

UNIVERSITY OF BRISTOL



THE ANNUAL REPORT

OF THE

Agricultural and Horticultural
Research Station

(THE NATIONAL FRUIT AND CIDER INSTITUTE)

LONG ASHTON, BRISTOL

1954

BATH :

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H. LOCKE (Horticultural Assistant). (*Retired 30 September, 1954.*)
MRS. R. LEWIS (Assistant Recorder).
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F. W. HYNAM (25).
K. J. ESCOTT (24).

Agricultural Research Council Unit of Plant Nutrition (Micro-Nutrients).

Honorary Director :

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E. J. HEWITT, B.Sc., Ph.D., A.K.C. (Seconded to Unit).
*D. J. D. NICHOLAS, B.Sc., Ph.D., A.K.C., F.R.I.C.
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H. M. STEVENS, B.Sc., Ph.D. (*Appointed 1 January, 1954*).
A. J. ABBOTT, M.Sc., Dip. Hort. (*Appointed 1 January, 1954*).
MRS. A. H. JAMES, B.Sc. (Hort.).
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*Returned 1 September, 1954, after two-year tenure of E. J. Johnson and Rockefeller Fellowships at the McCollum Pratt Institute, Johns Hopkins University, Baltimore, U.S.A.

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INTRODUCTION

By T. WALLACE, Director.

Following the year of the Coronation of Her Majesty Queen Elizabeth II and of the Jubilee of the National Fruit and Cider Institute, 1954 has seemed singularly free from outstanding events. Nevertheless there are many significant points to record which reflect the steady expansion of the work and interests of the Station.

The year has again been marked by close collaboration with the N.A.A.S. The usual annual refresher course for N.A.A.S. Horticultural Officers was held at the Station on 21st and 22nd July. It was attended by 62 N.A.A.S. Officers and 14 Horticultural Officers of County Council staffs. The subjects dealt with on this occasion included the nutrition of blackcurrants and strawberries; nutrient foliage sprays; molybdenum deficiency of crops and soil acidity effects; recent advances in materials for plant protection and in methods of application. In addition a special two-day grafting course for N.A.A.S. Fruit Officers was held in March.

A special event in the history of the South West Province of the N.A.A.S. took place on December 9th, when the new buildings of the Provincial Headquarters were opened at Burghill Road, Westbury-on-Trym, Bristol. The occasion was marked by the presence of Professor Sir James Scott Watson, Director General of the N.A.A.S. The Station was represented at the functions by Dr. Kearns in the unavoidable absence of the Director. This was also the last official visit to the Province to be paid by Sir James, who retired from his appointment on December 31st. Sir James is a very old friend of the Station, and we would wish to record our appreciation of his distinguished services to agriculture and horticulture, and to wish him and Lady Scott Watson much happiness in their retirement.

The Director has continued to serve on a number of official committees concerned with the various activities of the N.A.A.S. These comprise membership of the Agricultural Improvement Council; the Horticultural Committee of the Council, of which he is Chairman; the Advisory Committees of the N.A.A.S. Experimental Stations at Luddington, Efford, Rosemaund and Rosewarne; the Fruit Group, which is responsible for the Ministry of Agriculture bulletins and leaflets on fruit; and the Fruit Working Party, which considers proposals for experiments on fruit crops at the N.A.A.S. Stations.

It may also be recorded that the Station is now actively concerned with a number of experiments on fruit crops that have been established at the N.A.A.S. Horticultural Stations. These experiments should prove of great value to us in testing various research findings under varied conditions of soil and climate.

During the year several events occurred which are likely to lead to extensions of the Station's work in the Colonial Territories. Prior to 1954 the Colonial Office had called on the services of Dr. Kearns in connection with various spraying problems in the Colonial Territories, and it had gradually come to be realised that demands on Dr. Kearns' time were becoming increasingly heavy and likely to impede the progress of his work at Long Ashton. Thus in

January 1954 the Colonial Office, recognising the need to make further calls on the services of Dr. Kearns, proposed, through the Agricultural Research Council, that arrangements should be made to provide staff at Long Ashton to enable Dr. Kearns to carry out further work in the Colonial Territories without undue disturbance of his work at the Station. The situation has now been met by the provision of grants by the Colonial Office for the appointments of a workshops engineer, an entomologist and a mycologist. It is visualised that the two latter officers, after training at Long Ashton, will be available to undertake special problems as they arise in the Colonies. When the arrangement was made it was also recognised that the Colonial Office might wish to call upon the Station staff for problems in subjects other than mycology and entomology, and particularly for special problems in crop nutrition, with which the Station has hitherto been connected in the tropics through Dr. R. A. Webb, a member of the A.R.C. Plant Nutrition Unit who has been stationed in the Gambia. Dr. Webb's work in 1953 and 1954 has produced some striking results which have suggested new methods of attack on problems of the fertility of tropical soils. It would seem that in the testing of the new methods the Station is likely to play an important part, through Dr. Webb.

The interest of the Station in problems of tropical soils has also been further extended by a visit made to Nigeria by Dr. E. J. Hewitt, at the invitation of the West African Institute for Oil Palm Research at Benin, to examine nutritional problems of the oil-palm and to suggest a research programme on the mineral nutrition of this crop. Since his return Dr. Hewitt has reported his findings to the Institute and submitted proposals for future research.

The work on the fungicidal constituents of tar oil washes used in Malaya to control a disease of the tapping panel of rubber trees was concluded on July 31st, on the termination of the grant. The investigations have shown which constituents are responsible for the fungicidal properties of the oils, and the results should enable a closer standardisation and evaluation of tar oil preparations used for this purpose to be made in future. The Station has been happy to collaborate with the Rubber Research Institute of Malaya in this work, and is indebted to the Institute for the provision of grants to carry out the investigations.

The Cider Advisory Committee did not meet during 1954, but its Orchard-ing Sub-committee met at the Research Station on 3rd December to consider the need for revision of the list of varieties recommended in 1947. Although it was felt that no major alterations were needed at the present time, a small sub-committee was appointed to consider the matter further and also to report on varieties suitable for top grafting culinary sorts and on methods of taking crop-records.

The thanks of the Station are due to Messrs. Showerings, of Shepton Mallet, for the gift of a handsome photograph album containing colour transparencies of perry pear varieties. The series of photographs, when complete, will form an excellent set for reference in our studies of perry pear fruits.

The Cider Section received a visit from members of the A.R.C. Cider and Fruit Juices Committee, headed by Sir John Simonsen, Chairman of the Committee, on 9th September. The Committee inspected in detail the main laboratory investigations in progress and also saw some of the experiments in

the cider factory. The visit was much appreciated by the committee and the staff, and a similar visit has been arranged for 1955 to afford members who were not able to come in September an opportunity of doing so. In addition to this visit, Sir John Simonsen kindly paid a second visit on 12th October to discuss with us the research programme for 1955.

An opportunity to strengthen the collaboration between the Cider Section and the Brewing Research Foundation Centre at Nutfield, Surrey, occurred when the Director attended, as Chairman of the Technical Committee on Hop Research of the A.R.C., the European Brewing Convention at Nutfield on 19th and 20th May. Sir Ian Heilbron, the Director of the Research Centre, and Dr. Cook, the Deputy Director, are members of the A.R.C. Cider Committee. Unfortunately both were prevented from visiting Long Ashton in September, but it is hoped they will be present at the 1955 meeting.

In a letter dated 22nd July, 1954, from the Clerk to the Worshipful Company of Fruiterers, a generous offer was made by the Court of the Company to provide annually a medal or prize for competition among junior members of Station staff in respect of some scheme calculated to promote proficiency in their work. It was decided that the competition should take the form of an essay relating to any subject concerning fruit growing or fruit research. The competition, which will be confined to staff members up to and including Assistant Experimental Officers (University graduates excluded), will be held biennially, the first being proposed for 1956. Two prizes will be offered in each competition, comprising books to the value of £10 and £5 respectively. It is hoped that there will be a good response from the members of staff who are eligible. The Institute is grateful to the Company for this generous offer.

The first courses to be organised by the Food Preservation Section in Meat and Poultry Preservation were held in January and February, attendance being restricted to Rural Domestic Instructresses, with previous qualifications suited to this work. The N.A.A.S. Provincial Poultry Advisory Officer, Mr. G. E. Burkitt, undertook instruction on the suitability of poultry for preservation and on methods of killing and plucking, and his co-operation in this way was greatly appreciated. Other lectures and practical work concerned methods for bottling, canning and deep-freezing chicken, rabbits and pork, and discussion on the inclusion of this work in the County Instructresses' programme was led by H.M. Inspectors Miss M. L. Adams and Mrs. U. Cooling.

We are pleased to record the renewal, for a further period of seven years, of a grant from the Boots Pure Drug Company to provide a further three Boots Scholarships. The value of the scholarships for this second period has been increased to £400 per annum in order to attract first-class graduates. Each of the three scholarships will be of two years' duration, the first to date from 1st September, 1955. The Station is deeply grateful to Messrs. Boots for renewing this scholarship on such generous terms; the previous scholarships have provided the means for carrying out three valuable investigations.

On 16th February a Station broadcast was made in the Overseas Programme of the B.B.C. to France and Canada, dealing with those topics of the Station's work of particular interest to these countries.

On April 26th Professor C. E. Marshall, Department of Soils, University of Missouri, lectured at the Station on "The uptake of cations by plants." Professor Marshall is an authority in this field, and the staff are grateful to

the A.R.C. for providing the opportunity to hear Professor Marshall lecture on this subject.

On 19th October the A.R.C. Group concerned with problems of the effects of mineral deficiencies and excesses in animals held a meeting at Long Ashton, at which members of the Station staff contributed papers for discussion. On the following day the Group continued its deliberations at the University Veterinary Centre at Langford.

On 27th October we were pleased to welcome to the Station Sir John and Lady Russell, together with Sir John's three brothers. It was a pleasure to be able to hold with Sir John a more leisurely discussion of the Station's development than had been possible during his attendance at the Jubilee Celebrations.

We regret to record the death early this year of an old member of the Pomological staff, Mr. E. Umpleby. Mr. Umpleby joined the staff in 1925; he was originally employed as a fruit recorder and later was placed in charge of the Station nursery. He left us to take up a commercial post in 1948.

We should like to offer our congratulations to Major W. F. Q. Shulldham, representative of Somerset County Council on the Agricultural Committee, who was appointed High Sheriff of the County of Somerset for the ensuing year on 1st March, 1954.

It is pleasing to record the award of the O.B.E. to Dr. Kearns in the New Year's Honours. The services of Dr. Kearns to agriculture, both in this country and in the Colonial Territories, particularly with regard to the development of spraying equipment and methods of applying sprays, have been outstanding, and it was fitting that his valuable contributions in this field should be officially recognised. The award has given much pleasure to his colleagues at Long Ashton who also have long recognised his valuable and devoted services to the Station and to agricultural research.

It is also a pleasure to record the award of O.B.E. to Mr. F. Hirst, Director of the Chipping Campden Research Station, which until recently was administered by the Agricultural Committee of the University.

Staff.

Staff changes during the year were as follows :—

Appointments to scientific staff.

Mr. A. J. Abbott was appointed to the staff of the A.R.C. Unit of Plant Nutrition in the Plant Physiology section from 1st January, 1954. Mr. Abbott is a graduate in horticulture of Reading University. After graduating B.Sc. (Hort.) in Division I in 1951, he proceeded to a Diploma in Glasshouse Crop Husbandry (mineral nutrition), and later, with a post-graduate scholarship of the Ministry of Agriculture, he carried out research on day-length effects on plants, for which he was awarded the degree of M.Sc. in July 1954.

Dr. H. M. Stevens was also appointed to the staff of the A.R.C. Unit of Plant Nutrition from 1st January, 1954, as inorganic chemist in succession to Dr. W. A. Forster. Dr. Stevens is a graduate in chemistry of Bristol University. He gained his B.Sc. degree in Chemistry in 1951, and later carried out research work on the separation of the rare-earth elements by the method of paper chromatography, for which he was awarded the degree of Ph.D. in June 1954.

Dr. G. C. Whiting was appointed as biochemist in the Cider and Fruit Juices section from 8th June, 1954. He graduated B.Sc. at Sheffield University

with 1st Class Special Honours in Botany in 1936, and was awarded the degree of Ph.D. in 1938 for research work on plant respiration. During the war he served in the Ministry of Supply, first on the Chemical Inspectorate and later as a member of staff of the Flax Research Establishment, where he continued to work until he joined the Long Ashton staff. At the Flax Research Establishment his main researches related to the organic constituents of flax straw and fibre, particularly to the breakdown of pectins and the production of organic acids during flax retting. He also applied chromatographic methods to a study of the genetics of flax flower colour.

Dr. C. G. L. Furmidge was appointed physical chemist in the Entomology section from 1st September, 1954. Dr. Furmidge is a graduate of Nottingham University where he obtained his B.Sc. degree in Chemistry in 1950. After graduating he worked under a special A.R.C. grant on physical chemical problems relating to the action of insecticidal dips on sheep fleeces, and was awarded the degree of Ph.D. in 1953.

Mr. G. V. Coles, who had held a temporary post on the staff under a special grant from the Rubber Research Institute of Malaya, was transferred to a permanent post as head of the Analytical Group in the Chemistry of Insecticides and Fungicides section from 1st August, 1954.

Mr. E. Somers was also transferred to the permanent staff as physical chemist in the Insecticides and Fungicides section, from 1st October, 1954, on the termination of the special grant from the Agricultural Research Council for investigations on spray retention on foliage, under which he had held a temporary appointment.

Miss S. J. Perkins, Domestic Food Preservation section, was promoted from the Assistant Experimental Officer grade to the Scientific staff from 1st October 1954, to fill the post vacated by Miss M. Johnstone.

Appointments to assistant staff.

Mr. E. G. Bradfield, Experimental Officer, was appointed as analyst in the Nutrition of Fruit Plants section from 26th April, 1954. Mr. Bradfield took a special wartime course in chemistry and physics from 1942 to 1944, and then joined the Royal Air Force, in which he served until 1948. After leaving the R.A.F. he resumed his studies in chemistry as a part-time student at the Harris Institute, Preston, and the Manchester College of Technology, and gained the Associateship of the Royal Institute of Chemistry in 1952. During this period he was employed in the Chemical Inspectorate of the Ministry of Supply (Department of Atomic Energy), and as Assistant Chemist and Bacteriologist at the Manchester Corporation Waterworks.

Mr. J. A. Pickard, Assistant Experimental Officer, was appointed to a post in the Analytical Group of the Insecticides and Fungicides section, from 1st June, 1954. After army service between 1945 and 1948, Mr. Pickard was appointed to the staff of the Public Analyst in Bristol, where he continued until joining the Long Ashton staff.

Miss A. Cousin, B.Sc., Assistant Experimental Officer, was appointed microbiologist in the Cider and Fruit Juices section in succession to Miss J. H. Baker, from 1st August, 1954. Miss Cousin came to us after graduating B.Sc. (Honours) in Botany in Bristol University in June 1954.

Mr. E. A. Baker, Assistant Experimental Officer, was appointed assistant analyst in the Chemistry of Insecticides and Fungicides section, from 1st

October, 1954, having previously been employed in the Public Analyst's Department in Bristol.

Miss J. Sherborne, B.Sc., Assistant Experimental Officer, was appointed microbiologist in the Domestic Food Preservation Section from 8th November, 1954, having graduated B.Sc. (Honours) in Botany in Bristol University in June 1954.

Miss E. Atkinson, B.Sc., Assistant Experimental Officer, was appointed for microbiological work in the A.R.C. Unit of Plant Nutrition, from 22nd November, 1954, in succession to Mrs. M. V. Taylor. Miss Atkinson had graduated B.Sc. (Honours) in Agricultural Botany in Durham University in July 1954.

Miss P. M. Hammond, Assistant (Scientific), Microbiology, Cider and Fruit Juices Section, from 1st June 1954.

Mr. G. J. Dickes, Assistant (Scientific), A.R.C. Unit of Plant Nutrition, from 1st December, 1954, to succeed Mr. D. A. Lewis.

Retirement.

Mr. H. Locke, who had been employed at the Station since 1916, finally retired on 30th September. In his early years at Long Ashton Mr. Locke held the post of Plantations Foreman; he later acted as Station Guide and Meteorological Officer and also assisted in the Pomology section. He retired from his full-time employment in 1940, and since then he had been engaged on part-time work in pomology. He had a unique knowledge of fruit varieties and much of his time in later years had been occupied in identifying fruits sent to the Station. His services had also been in great demand as a judge at horticultural shows, at which he was a well-known figure. Mr. Locke had always been a most popular member of staff, to whom all had turned at some time for advice on pomological matters. His retirement was marked by a staff tea party at which Mr. Locke received a small present to remind him of his long and happy period of service at the Station.

Resignations.

Miss M. Johnstone, Domestic Food Preservation section, resigned from 18th September, 1954, to take up a post in medical bacteriology at Southmead Hospital, Bristol.

Resignations of assistant staff were as follows :—

Mrs. M. V. Taylor, Assistant Experimental Officer, A.R.C. Unit of Plant Nutrition, from 31st May, 1954.

Miss J. H. Baker, Assistant Experimental Officer, Cider and Fruit Juices section, from 22nd July, 1954.

Mrs. P. M. Pope, Assistant Experimental Officer, Insecticides section, from 30th September, 1954.

Miss Y. P. May, Assistant Experimental Officer, Cider and Fruit Juices section, from 31st December, 1954.

Miss J. R. Brown, Assistant (Sc.), A.R.C. Unit of Plant Nutrition, from 31st May, 1954.

Mr. Graham H. Jones, Assistant (Sc.), A.R.C. Unit of Plant Nutrition, from 25th September, 1954.

Mr. D. A. Lewis, Assistant (Sc.), A.R.C. Unit of Plant Nutrition, from 15th September, 1954.

Miss M. M. Hooper, Assistant (Sc.), Domestic Food Preservation section, from 18th September, 1954.

Mr. G. Bracey, Assistant (Sc.), Entomology section, from 15th December, 1954.

Appointments to administrative staff.

Miss J. M. Walters, Shorthand-typist, from 26th April, 1954.

Mrs. M. Wippell, Shorthand-typist, from 8th November, 1954.

Resignations.

Miss V. E. R. Alsop, Shorthand-typist, from 19th April, 1954.

Miss S. R. Littlewood, Shorthand-typist, from 8th October, 1954.

Mrs. B. E. Stiddard, Clerical Officer (temporary appointment) from 31st October, 1954.

Visits Abroad.

Dr. H. G. H. Kearns, at the request of the Colonial Office, visited the East African Colonial Territories of Kenya, Tanganyika and Zanzibar from 13th January to 24th February, 1954, to examine problems of the control of the coreid bud (*Theraptus* sp.) on coconuts and other pests on coffee, tea, seed beans, maize and cashew nuts.

At the invitation of the Government of Jamaica he also visited that Colony from 3rd to 28th May, to survey the progress made since his previous visit in the control of Leaf Spot Disease of bananas.

Dr. D. J. D. Nicholas, A.R.C. Unit of Plant Nutrition, returned from the McCollum Pratt Institute, Johns Hopkins University, Baltimore, U.S.A., on 1st September, 1954, on the conclusion of his two-year tenure of the E. J. Johnson and Rockefeller Fellowships.

Dr. D. Woodcock was absent on leave for the six months period January-July 1954, whilst holding a Kellogg Research Foundation Fellowship in the Department of Entomology, University of California, Berkeley, California.

Dr. E. J. Hewitt visited the West African Institute for Oil Palm Research, Benin City, Nigeria, from 1st September to 4th October, 1954, at the request of the Managing Committee and Director of the Institute, to advise on problems of the nutrition of the oil-palm.

Dr. L. C. Luckwill proceeded to Cornell University, U.S.A., in June to take up the post of Visiting Professor in Pomology for a period of one year, dating from 1st July, 1954.

The Director and Dr. E. J. Hewitt attended the 8th International Botanical Congress in Paris from 2nd to 14th July, 1954.

Degrees, Honours, etc.

Dr. H. G. H. Kearns received the award of the O.B.E. in the New Year's Honours.

Mr. R. W. Marsh delivered the 1954 Fernhurst Lecture on "Modern Developments in Fungicides" at the Royal Society of Arts on 17th February, 1954.

The degree of Ph.D., Bristol University, was awarded to Mr. H. M. Stevens for a thesis entitled "The application of paper chromatography to the separation

of the rare earth elements," and the degree of M.Sc., Reading University, was awarded to Mr. A. J. Abbott for a thesis entitled "Photoperiodic and developmental responses of some annual plants in relation to nutritional conditions."

Mr. B. Notton, Assistant Experimental Officer, was successful in the examination for the Associateship of the Royal Institute of Chemistry (A.R.I.C.)

Buildings and Land.

During the year plans for two major building projects were prepared, viz. : a greenhouse block with special-purpose laboratories attached, and a laboratory to accommodate the biochemical work of the A.R.C. Unit of Plant Nutrition and the Analytical Team recently added to the Station staff to investigate methods of analysis of insecticides and fungicides. The plans were completed and agreed by the Ministry of Agriculture and the Agricultural Research Council during the autumn, and tenders for the work were received on 22nd November, 1954. Following the receipt of the tenders a contract for the two projects has been signed with Messrs. John Knox (Bristol) Ltd. for the work to begin early in January 1955.

Negotiations have also continued with the Agricultural Research Council and the Ministry regarding the provision of a new block of laboratories and offices and a canteen, the building of which it is hoped will follow closely on the completion of the greenhouse block. It is now proposed that the laboratory and office block shall occupy a site in the northern section of the old cider orchard near the main Station entrance from the Bristol to Weston-super-Mare road, and that the canteen block, which will comprise a canteen, kitchens and staff common room, will be situated on Plot 2, immediately to the east of the northern section of the old cider orchard and near the plantation road. The site and plan proposed for the laboratory and office block will allow of any extension of laboratories and offices that may be needed in the future.

During the year discussions took place with officers of the Somerset County Council and of the Town and Country Planning Authority regarding the routing of a proposed by-pass road for Long Ashton village across the Station property on the south side of the main road. The final proposals regarding the route are still awaited.

For many years the private sewer of the Station has been used to take the drainage from a number of private properties adjoining the Station. It has now been arranged that this sewer shall be taken over by the Local Authority.

The arrears of exterior painting were completed during the year. To avoid the likelihood of arrears of painting accumulating in future, an additional painter has been appointed to the staff of the Maintenance Section, so that the property may be maintained in good condition and the cost spread more evenly on an annual basis.

On the farm the programme of clearing the older experimental plots was continued. The main area to be cleared was Plot 22 (standard apple tree root-stock trial), preparatory to future plantings of bush fruits. The standard cider apple orchard near the main entrance to the Station, which was originally planted in 1903-5, has suffered a number of casualties of recent years due to trees blowing over in gales and also to the sporadic spread of *Armillaria mellea*. Gaps are therefore appearing in this orchard, but it still contains some very fine trees.

The Dwarf Pyramid planting scheme has been completed, and some 4,800 trees are now growing on Plots 13 and 16, and will provide field experimental material for various departments of the Station. The bush fruit stool nursery on Plot 5, planted in 1945, is in need of renewal and is being replaced by new plantings of black and red currant and gooseberry stool plants on Plot 6, from which future cutting wood will be taken.

Research Activities.

Plant Nutrition : Fruit.

Work on the nutrient status of Climax strawberry leaves in relation to time of sampling, manurial treatment and yield of fruit has been published during the year. Evidence since obtained from plots of Royal Sovereign at Rosewarne has confirmed that the strawberry can mobilise soil phosphorus not readily available to other crops.

Field trials of iron chelates for the control of lime-induced chlorosis have been extended; successful results with plum, pear and peach have been obtained with soil dressings or foliage sprays. It has been shown that iron chelates are photosensitive: this may explain the release of iron for plant metabolism from otherwise stable compounds. Laboratory perfusion tests have so far given no indication that grass leachates can mobilise iron from calcareous soils.

A number of long-term factorial manurial experiments have been started at N.A.A.S. Horticultural Experiment Stations, using strawberries and blackcurrants to study the relationship between growth, yield of fruit and the chemical composition of the leaves. A new experiment with blackcurrants has been started at Long Ashton in order to determine the effects of deficiency, optimum and luxury levels of nitrogen in the presence and absence of potassic and phosphatic fertilizers.

The investigation of an abnormal condition in the bark of apples growing on a strongly acid soil is described in the present Report.

Pomology and Plant Breeding.

In an attempt to control the "running off" of blackcurrants, the varieties Seabrook's Black and Westwick Choice were sprayed with naphthalene acetic acid. Treatment was, however, found to increase the drop of berries, but when applied shortly after fruit set it resulted in a 10% increase in mean berry weight which compensated for the reduced number of berries.

Further observation has shown that the success of 2:4:5 trichlorophenoxy propionic acid as a fruit-ripening agent is likely to be offset by its damaging effect on the tree in the year following treatment. In experiments described in this volume trees of Worcester Pearmain sprayed in 1953 yielded crops in 1954 as low as 25% of those obtained from control trees, the degree of damage being dependent upon the time of application of the spray. Further trees have been sprayed in order to provide more information on the residual effects of treatment.

It has been found possible to cut young apple fruitlets in half transversely, thus exposing the seeds, without causing abscission. By the subsequent removal of varying numbers of seed at different times, pilot experiments have been carried out to determine the effects of seeds upon fruit growth and development. The application of naphthalene acetic acid in lanolin to cut apples from

which all seeds had been removed enabled the fruitlets to continue to grow and develop to maturity.

Studies of the dormancy of apple seeds have shown that the after-ripening process is reversible and that a "compensation" temperature of approximately 17°C. exists at which neither after-ripening nor reversal normally occurs.

Following the survey of the perry orchards of North-west Gloucestershire, a survey is now being carried out in South Herefordshire. Pomological descriptions have been prepared of over 100 varieties of perry pear, 11 of which are illustrated in this Report.

The vegetative and floral characters of approximately 150 varieties of gooseberries have been described and the suitability of these characters for the identification of varieties is being studied. Experiments to determine the effects of shoot length and basal wounding on the rooting of gooseberry cuttings are described in the present volume.

Pests and Diseases and their Control.

Work has continued on the effect of changes in the structure of organic compounds upon their activities as insecticides, fungicides or growth-promoting substances. During his stay at the University of California, Dr. Woodcock re-examined the toxicities of compounds in the DDT series synthesized at Long Ashton. Derivatives of 8-hydroxyquinoline and various new 2-nitro-alkyl phenols have been prepared for evaluation as fungicides, and further members of the 2-naphthoxyaliphatic acid series have been synthesized in work on parthenocarpic agents.

Investigations on the inter-relationship between fungicidal and phytotoxic action have continued with the examination of further derivatives of pentachlorophenol. The lower fatty acid esters were more fungitoxic than the higher esters and the methyl ether, and the rates of hydrolysis of the esters correlated satisfactorily with their activities.

Work on the fungicidal components of tar preparations used against the mouldy rot fungus of the rubber tree has now been completed. An improved experimental design for bioassay has been developed, and a new method of chemical analysis is described in this volume. The value of the tar phenols in controlling the fungus has been confirmed.

Radioactive tracers have been used in joint work between sections. Further information has been obtained on the absorption, translocation and breakdown of demeton-S in plants, and on the extent of contamination of nectar. It has been shown to be readily translocated when applied to the roots of apples and beans, but not when applied to the leaves. The autoradiographic technique has been developed and used to study the movement of copper from fungicide deposits, the fixation of copper by spore suspensions and in work on lime-induced iron chlorosis.

Work has continued on problems arising in the application of spray materials. A method developed for the determination of small amounts of captan is described in this volume; it has been used to assess its persistence on strawberry, raspberry, apple and pear fruits and foliage. Other work has been devoted to the determination of DDT and chlorbenside deposits in the presence of each other. The effect of formulation on the levels and persistence of insecticide and fungicide deposits has been examined and the analysis of residues has been used to assess the performance of spraying machines.

The formation of the Analytical Team has enabled us to extend our investigations on spray application problems and to give assistance to officials at home and overseas. Among the investigations undertaken for the Ministry of Agriculture has been the examination of bees suspected of spray poisoning.

A study of the biology of the Leaf Curling Plum Aphid has been completed and prepared for publication. Investigations of the pupation and emergence of the Button Top Midge of basket willows are being continued with a view to devising control measures.

The bioassay of DDT isosteres and nitro derivatives has shown marked insect specificity. The failure of DDT to show contact activity against the locust appears to be due to its inability to pass the cuticle. Preliminary work supports the hypothesis that the activity of DDT is confined to the conducting properties of the nerve.

Experiments described in the Report have shown that nearly 100 per cent. control of the winter eggs of the Fruit Tree Red Spider may be obtained by the application of chlorbenside at 0.05 per cent. just before egg-hatch. The inclusion of an acaricide in a combined DDT-BHC emulsion promises to establish spring spraying as a complete substitute for winter washes.

In an investigation of Banana Leaf Spot in Jamaica it was found essential to provide complete coverage of newly opened leaves with copper fungicides to prevent ascospore infection. Spray formulations have been devised and specifications for equipment suitable for use in the tropics are given in the present volume.

Biological assays of spray deposits, using *Botrytis fabae* as a test organism, have shown that a considerable increase in concentration of lime sulphur is needed to compensate for lack of uniformity in distribution. Small droplets of Burgundy mixture were found unable to prevent *Botrytis* lesions if the copper carbonate were free from soluble copper.

In further comparisons of large-volume and small-volume sprays for apple scab control, trials on Cox and Worcester indicated that six air-flow applications of 2% lime sulphur at 50–100 gal. per acre gave a level of scab control almost equal to that provided by five hydraulic 1% lime sulphur sprays at 400 gal. per acre. The plots receiving the small-volume sprays showed the highest yields and the least russetting.

Plots of Climax strawberries sprayed three times with either 0.4% thiram or 0.25% captan showed one-third the *Botrytis* infection of corresponding unsprayed blocks. Salicylanilide (0.2%) and tetrachloronitrobenzene (0.2%) gave no field control. The maximum level of captan residue recorded on the ripe fruit was 19 p.p.m. None of the spray residues showed any adverse effect on fresh fruit or jam, but in the canned fruit marked tainting was found in the thiram-sprayed berries and slight tainting in those that had been sprayed with captan.

Field inoculations with the *Gloeosporium* spp. causing apple storage rots showed that late-autumn infection by *G. perennans* could induce extensive cankering on shoots of Cox's Orange Pippin. Spores were produced on *Gloeosporium* cankers from May to October.

In tests of eradicant fungicides against the over-wintering stage of *Pseudopeziza ribis* on dead blackcurrant leaves, the following materials suppressed spore production: 0.05% phenyl mercuric chloride, 0.1% dinitro-cresol and 0.1% sodium pentachlorophenate.

Cider and Fruit Juices.

Cider and perry. In studies of fermentation further experiments have been made with pure yeasts, whose use in vintage trials is advocated in an article in the present volume summarizing the results obtained in the Variety Trials laid down in 1935. In commercial cider-making the use of sulphiting techniques for controlling the natural juice flora is of more immediate interest and has many advantages. The chemical and microbiological changes occurring in juices and ciders are being followed throughout various fermentation procedures.

A survey of the amino-acids present in apple and pear juices and in the derived ciders and perries has shown that whereas asparagine, aspartic acid and glutamic acid are the main components of apple juice, the dominant amino-acid in pear juice is proline, asparagine occurring in only small amount. Proline and methyl hydroxy proline are the main components of perry whilst methyl hydroxy proline is prominent in ciders. As the fruit approaches maturity there is a progressive fall in the soluble nitrogen content of apple and pear juices and a reduced content of most amino acids. α -Alanine and proline are exceptional and are present in greatest amounts in the juices from rotten fruits. In pear juice this change is accompanied by a reduced tendency to form hazes or deposits. It has been found that the uptake of amino-acids by yeasts is dependent on the nutritional status of the juice: the correction of thiamine deficiency gives a more complete utilisation of nitrogen, leading to ciders of greater stability.

The main changes in organic acids during fermentation have been found due to the action of lactic acid bacteria on malic and quinic acids and to the production of succinic acid by yeasts. In ciders bacterial breakdown of malic acid leads to lactic acid and sometimes to succinic acid; in both ciders and perries quinic acid is reduced to dihydroshikimic acid whilst the breakdown of the citric acid present in some varieties of perry pear may lead to an increase in volatile acidity. The metabolism of quinic acid is of interest because of its possible function in aromatic biosynthesis.

A wide range of lactic acid bacteria has been isolated from juices; their metabolism is being studied in detail in the course of their classification. An account of improved methods developed for the isolation of yeasts and bacteria has been published during the year. Of the 120 yeast isolates examined in detail a number appear to represent new strains or species.

Unfermented juice products. The stability of bottled apple juices has been further investigated, and deterioration in storage is being related to changes in individual components of the juices. The production of deposits in stored juices appears to be associated with changes in the leucoanthocyanin component. The catalytic effects of metals, notably copper, are being closely studied. Determinations of the amounts of copper, iron, zinc and lead present in apples and their juices have shown that the highest concentrations occur in the peel. This distribution is thought to be natural, though some high values have been obtained in fruits subjected to atmospheric pollution.

Work on fruit-juice concentrates has been extended, and attractive products have been prepared from blackcurrants, raspberries and strawberries. The quality of the finished products is dependent on storage conditions: at deep-freeze temperatures they remain stable for long periods, whereas at

temperatures above 0°C. deterioration is rapid and leads to losses of ascorbic acid, to changes in colour and eventually to adverse changes in flavour.

Domestic Food Preservation.

The preservation of meat and poultry, undertaken in 1953 at the request of the Ministry of Food, has again been given priority in the research programme. Although further trials are needed before sufficiently reliable methods of deep-freezing and heat preservation can be recommended to the housewife, it was possible to demonstrate the progress achieved to selected classes of County Instructresses in Rural Domestic Economy at the beginning of 1954.

Studies of heat preservation have entailed inoculation tests with heat resistant organisms on 900 treated samples of meat and 450 controls; records of heat penetration have also been obtained during the processing of standard containers of various sizes. The successful deep-freezing of pork has been found to depend on the correct choice of wrapping material and on limiting the period that elapses between the slaughter of the animal and the freezing of the meat.

The conditions needed for the destruction of *Bacillus thermoacidurans*, an organism causing spoilage in tomato products, have been determined at the higher pH ranges of tomatoes. Its heat tolerance in more acid conditions is being studied.

The present volume contains an account of trials in which 15 varieties of raspberry and 9 varieties of strawberry were compared when fresh and again after storage by bottling and deep-freezing. Plums and locally grown peaches are amongst other fruits tested during the year. Light-fleshed plums that had been preserved by deep-freezing were found to discolour badly whilst thawing.

A summary is also given of comparative trials of freezing and canning carried out with some varieties of peas and beans in at least three of the years between 1949 and 1954. The superiority of the frozen products in colour, texture and flavour was very marked. The effects of maturity on the preserving quality of vegetables are being studied, and the wastage entailed in their preparation is being determined.

Ministry Bulletin No. 21, *Domestic Preservation of Fruit and Vegetables*, has been revised to include newer methods of bottling and information on deep freezing, and a Fruit Bottling leaflet was issued by the Station during the year.

Willows.

The examination of varietal characteristics likely to assist in the classification of basket willows has been continued; it seems unlikely that leaf size can serve as a diagnostic character because of the large range in length and breadth found within a variety. A study of the growth-rates of 12 varieties of *Salix triandra* has shown differences that may in part be due to their susceptibility to pests and diseases. The mean daily growth increment was 1.6 cm. during the period mid-May to mid-September and reached a maximum of 3.3 cm. in mid-June.

The rooting system of basket willows has been studied in order to determine what damage is likely to result from the use of mechanical cultivators to control spring weeds. Very different results were obtained in two beds of cuttings: in one bed nearly 90% of the first year's root growth was found to occur in the surface 6 in. of soil while in the second bed the proportion was only 53%.

An alternative method of weed control is the use of tar-oil sprays. A marked set-back to young willow shoots was found when sprays ranging from $3\frac{1}{2}$ to 12 per cent. concentration were applied with and without wetting agent ; concentrations exceeding 8 per cent. caused the death of the shoots.

There were 163 requests for information during the year and many applications for planting material. Among additions to the variety collection are four species imported from North America because of the demand for willow peelings rich in salicin. The basket-making qualities of these species are being studied before issuing them for trial by growers.

A survey of the Somerset willow-beds was made in September and 41 growers, including 5 in the Midlands and 4 in East Anglia, were visited during the year.

Statistics.

Designs have been prepared for a number of experiments in the Station's greenhouses and laboratories and in the field ; the latter include long-term layouts for plot 18 (apple nutrition ; manurial and cover-crop trial) and for plots 21 and 22 (blackcurrants ; spraying, nutritional and varietal trials). A design has been evolved for incubator work, which enables several sources of variation to be eliminated ; this has been employed in work on tar-oil fungicides and has extensions to layouts in fruit storage trials.

The results of an examination of the variability in sampling blackcurrants for leaf-spot are reported in this volume ; in such work it appears necessary to deploy available labour so as to sample from as many individual bushes as possible. Preliminary work has also been carried out to examine variations in environmental conditions in the large pot-culture greenhouse ; this when complete will aid in choosing the best designs for experimental work in the house.

There has been a rapid increase in the number of requests for designs and analyses of experiments, and also for the planning of sampling procedures to improve the quality of basic recorded data.

Agricultural Research Council Unit of Plant Nutrition (Micronutrients).

Molybdenum nutrition. The study of the valency states of molybdenum compounds present in extracts of cauliflower leaves was continued. It was confirmed that plants given hexavalent molybdenum as molybdate contain hexavalent, pentavalent and lower valency compounds. The proportions of the different valency states vary according to differences in nitrogen and manganese supply and under different conditions of light and aeration. The hexavalent fraction is apparently complex, as revealed by differences in reaction with thiocyanate.

The methods of growth analysis have been applied to the study of the effects of molybdenum supply on the growth pattern of the tomato. Growth and nett assimilation rates were not decreased by molybdenum deficiency until some time after the appearance of visual symptoms. The supply of $0.15\text{ }\mu\text{g}$ Mo during the first 7 days after sowing prevented any decreases in growth rate for 46 days, though visual symptoms of deficiency occurred in 27 days compared with 17 days in plants from which molybdenum had been omitted from the beginning. A number of technical difficulties have temporarily halted this work.

Further work on seed reserves of micronutrients has shown that dwarf beans may hold sufficient molybdenum for two generations' growth under deficiency conditions. Deficient seeds are able to produce normal plants when supplied with a complete nutrient.

Essentiality of Elements for Plants. Water-culture experiments with tomato, using carefully selected materials and purified reagents, failed to reveal evidence of any requirement for V, Cr, Co, Ni, Ga, Cd, Ru, Rh, Tl, Sn. The work is being continued.

Methods. Polythene was tested for its inertness with respect to molybdenum and copper contamination and found to be comparable to Pyrex glass. Work was begun to devise methods for growing cauliflower plants in water culture and for using ammonium compounds in water culture as distinct from sand culture.

Mineral Nutrition of Micro-organisms : Enzymes. In work at the McCollum Pratt Institute, Dr. Nicholas and his collaborators showed molybdenum to be a constituent of the flavoprotein enzyme, nitrate reductase, which catalyses the reduction of nitrate to nitrite in bacteria, fungi and the higher plants. The micronutrient undergoes oxidation-reduction changes from $\text{Mo}^{(vi)}$ to $\text{Mo}^{(v)}$ during the transfer of electrons from reduced pyridine nucleotides via flavin to nitrate. Thus a specific role in plant metabolism has been assigned to molybdenum for the first time. In molybdenum deficient tissues the activity of glutamic hydrogenase was found to be significantly reduced.

In *Neurospora crassa* two metallo-flavoproteins have been characterised which catalyse the reduction of nitrite to ammonia and hydroxylamine to ammonia. The enzymes can be separated by ammonium sulphate fractionation. Reduced diphosphopyridine nucleotide serves as the electron donor for both enzymes.

The effect of iron and molybdenum status on the respiratory enzymes of *Pseudomonas fluorescens* has been investigated. Iron deficiency resulted in a marked reduction in the iron enzymes (catalase and cytochrome C peroxidase) and in an increase in the flavoprotein enzymes (diaphorase, nitrate and nitrite reductase). Molybdenum was without effect on the iron enzymes but reduced the flavoprotein enzymes. It is thus possible to change the mode of electron transport from a cytochrome pathway to a flavoprotein one by varying the iron and molybdenum status of the bacteria.

The trace-metal nutrition of *Neurospora* and *Azotobacter* have been studied with particular reference to Fe, Zn, Mo.

Leaf Analysis. A washing method, now in routine use, has been devised to remove surface contamination of iron from leaf samples prior to analysis.

Indicator Plots. The experiment plots established in 1952 on four farms in which conditioned copper deficiency had appeared in sheep and cattle were seeded down to four grasses in 1954. The grasses showed no response to copper treatments.

Carrots were grown on an acid soil on the Lower Greensand in which test-crops of lettuce and various brassicae had been grown in the previous three years. An account of the experiment is given in this Report. There was marked response to applications of limestone but none to soil-dressings or foliage sprays of sodium molybdate. Seedlings showed a purpling of the cotyledons and a chlorosis of the leaf margins indicating aluminium and manganese toxicities respectively.

Magnesium Deficiency in Grasses. In preliminary work for the Animals Sub-Committee, Aberystwyth strains of four grasses, Cocksfoot (S.143), Meadow Fescue (S.53), Perennial Rye (S.23) and Timothy (S.48), were grown in sand cultures using nutrient levels of magnesium ranging from 0 to 24 p.p.m. The magnesium contents of the grasses are being determined. A banded type of chlorosis occurred in all four grasses at the lowest level of magnesium; necrosis showed only on Rye grass and Meadow Fescue whilst tip burn occurred only with Timothy.

Organic constituents of plants. A derivative of *p*-coumaric acid, very probably *p*-coumaryl quinic acid, has been found in the leaf and fruit of the apple and pear. Investigation of other phenolic constituents, especially flavonols and leuco-anthocyanins, continues.

Paper chromatography of leaf extracts from pear-apple hybrids, kindly supplied by the John Innes Horticultural Institution, has shown the presence of all the typical phenolics of both parents.

Other Activities.

Members' Day.

The annual Field Day for Members was held on 29th July on the occasion of the Annual Meetings of the Members and the Governors. The main demonstrations illustrated methods for the high working of plums against Bacterial Canker, systems of planting apples and of establishing young apple trees in grass sward. Exhibits of special features were also staged in the laboratories, pot culture enclosure and cider house.

Cider Sampling Day.

The Annual Sampling Day was held on Thursday, 6th May, and was well attended by cider makers, cider fruit growers and others interested in cider matters.

On this occasion, in view of the renewed interest in perry making, the first section of the programme consisted of comparisons of single varieties and blends of perries, made from fruits grown on a wide range of soils. In making the perries great care had been taken to ensure that the fruits were milled at the right stage of maturity, a point of great importance in perry making. The excellence of a blend of Moorcroft and Yellow Hufcap was particularly notable.

The second part of the programme illustrated the effects of fermenting ciders, after sterilising the juice, with pure cultures of yeasts instead of fermenting in the usual way with the natural mixed flora of the juice. The ciders made from the pure yeast cultures were unanimously preferred, those made with Steinberger yeast being especially commended.

The value of using pure yeasts in making comparisons of the cider-making properties of fruits from different sites and at different stages of maturity was also demonstrated.

In the third section some ciders made from little-known early varieties of apples from Devon were shown. The interest in these lies in their possible use to lengthen the cider-making season, since at the present time there is a dearth of varieties for early milling. The ciders were all made from varieties of good local repute and included sweets, bittersweets, bittersharp and sharps.

The general exhibits shown in the cider house included a chart displaying the results of pollination experiments with cider apple varieties, the possibility of metallic contamination from plant during cider-making processes and a demonstration of simple methods for detecting iron and copper in ciders. During the afternoon demonstrations were given in the plantations relating to grafting methods, frameworking of mature trees and spraying methods.

Visitors.

The number of organised parties visiting the Station was 68 compared with 50 in 1953 and 43 in 1952. Besides the courses in Horticulture and Domestic Preservation already referred to, two courses in Wine-making were given to County Instructresses in Rural Domestic Economy. Visitors included delegates to the Fifth Commonwealth Mycological Conference and to the Summer Meeting of the Institution of Electrical Engineers.

Organised Parties, 1954.

A.R.C. Group on Mineral Deficiencies and Excesses in Animals.
 All Saints, Clifton, Literary Club.
 Association of Teachers of Domestic Subjects.
 Birmingham University Botany Students.
 Boot and Shoe Trade Managers' and Foremen's Association.
 Brislington Horticultural Association.
 Bristol Grammar School Agricultural Society.
 Bristol Old Comrades' Association, Women's Section.
 Bristol Teachers' Association.
 Bristol University Microbiology Class.
 Bristol University Settlement.
 Bristol University Spelaeological Society.
 Bristol University Young Farmers' Club.
 Cardiff University College Biological Society.
 City of Bath Training College.
 City of Bath Boys' School.
 City of Bristol Young Farmers' Club.
 Club 52, Bristol.
 Colston's Boys' School.
 Colston's Girls' School.
 County Instructresses in Rural Domestic Economy—
 Wine-making Courses (2).
 Diocesan Training College, Barrow Court.
 Diocesan Rural Study Group.
 Domestic Preservation Course, Fruit and Vegetables.
 Domestic Preservation Courses, Meat and Poultry (3).
 Easton-in-Gordano Women's Institute.
 Fifth Commonwealth Mycological Conference.
 Filton Secondary Modern School Rural Science Class.
 Fishponds Townswomen's Guild.
 French Horticultural Officers.
 Gloucester Training College for Domestic Science (3).
 Henbury District Allotment Association.
 Herefordshire N.F.U.
 Horticultural Education Association Officials.
 Ilfracombe Grammar School.
 Institute of Medical Laboratory Technology.
 Institute of Electrical Engineers.
 International Club, Bristol.
 La Retraite Convent, Salisbury, Science Society.
 Lower Lansdown, Bath, Townswomen's Guild.
 N.A.A.S. Agricultural and Specialist Officers (3).
 N.A.A.S. Grassland and Horticultural Officers.
 N.A.A.S. Horticultural Officers, Propagation Course.

N.A.A.S. Horticultural Officers, Refresher Course.
 Nottingham University Horticultural Students.
 Oldland Women's Institute.
 Plant Protection Students, British Council.
 Portway Boys' School.
 Ramblers' Association, South West Area.
 Reading University Horticultural Students (2).
 Redland Training College.
 Regional Council for Further Education for the South West.
 St. Paul's College, Cheltenham.
 Stoke Bishop Townswomen's Guild.
 Scottish Fruit Trials Officers.
 Somerset Farm Institute, Cannington.
 Somerset Teachers.
 West of England Child Health Group.
 Weston-super-Mare Grammar School for Girls.
 Wiltshire Education Department, Rural Subjects Teachers.
 Yugoslav graduates.

There was a large increase in the number of visitors from overseas, some of whom had been attending the Eighth International Botanical Congress in Paris.

Visitors from Overseas, 1954.

<i>Argentina :</i>	Mr. R. G. Lynen, Buenos Aires.
<i>Australia :</i>	Mr. T. C. Creyke, Canberra. Mr. J. Fisher-Pollard, Melbourne. Dr. J. C. M. Fornachon, Waite Research Institute, Adelaide. Mr. H. Halliday, South Australia. Mr. H. S. Hunter, Brisbane. Mr. D. Kentish, Keith, South Australia. Mr. L. N. Lane, Sydney. Dr. C. J. Magee, Sydney. Dr. C. R. Millikan, Melbourne. Mr. K. W. Nicholls, Tasmania. Mr. A. C. Orman, Sydney. Mr. N. R. Pither, Victoria. Mr. R. Roe, C.S.I.R.O., Armidale, New South Wales. Dr. G. A. Stewart, C.S.I.R.O., Canberra. Professor L. J. H. Teakle, University of Queensland. Mr. J. C. Walsh, Commonwealth Fresh Fruit Officer. Mr. D. V. Walters, Griffith.
<i>Barbados :</i>	Mr. J. Bolton, Department of Agriculture.
<i>Belgium :</i>	Monsieur A. Brixhe, Brussels.
<i>Bolivia :</i>	Mr. E. Yanez, Agricultural Department.
<i>Canada :</i>	Dr. W. A. Andreae, London, Ontario. Professor D. L. Bailey, University of Toronto. Dr. A. D. Pickett, Kentville, Nova Scotia. Dr. M. J. Welsh, Summerland, British Columbia.
<i>France :</i>	Dr. R. Contin, Versailles. Dr. D. Morel, Versailles.
<i>Gambia :</i>	Mr. H. Bailey, Department of Agriculture. Mr. R. S. Liney, Department of Agriculture.
<i>Germany :</i>	Dr. O. Kohnke, Hanover. Dr. B. P. Kopf, Hanover. Dr. W. Linke, Leverkusen. Mr. W. Schubert, Hanover. Mr. Udo Schwertmann, Hanover. Mr. Paul Seyther, West Ems. Frau Siche-Tarnowski, Berlin.
<i>Gold Coast :</i>	Miss B. Störn, Hofzahl. Mr. K. Christian, Kumasi. Mr. John Francois, Accra. Mr. P. H. Nye, University College. Mr. R. A. Silverlock, Agricultural Department.

- Greece :* Dr. C. Catsimbas, Athens.
Grenada : Mr. D. Wallace, Agricultural Department.
Haiti : Mr. Joseph Adrien, Department of Agriculture.
Holland : Dr. de Bakker, Deputy Director of Horticulture.
 Dr. K. B. A. Bodlaender, Wageningen.
 Mr. van Hennik, Horticultural Adviser, Zeeland.
 Mr. J. Koopmans, Boehesteyn Experiment Station.
 Dr. J. A. van der Loeff, Groningen.
 Mr. A. J. Reestman, Wageningen.
India : Professor J. W. Airan, Wilson College, Bombay.
 Mr. R. D. Green, Dooars, West Bengal.
 Mr. Gundas Singh, Bikaner.
 Dr. E. S. Narayanan, New Delhi.
 Dr. G. A. Patel, Poona.
 Dr. B. Ramamoorthy, New Delhi.
 Dr. Rattan Lal, New Delhi.
 Dr. W. V. B. Sundara Rao, New Delhi.
Iraq : Mr. A. R. I. Al-Adhami, Baghdad.
Israel : Dr. J. Aman, Hebrew University, Jerusalem.
 Dr. K. R. S. Ascher, Medical Corps.
 Mr. Dov Barak, Habirya.
 Mrs. Sylvia Guelfat, Tel-Aviv.
 Dr. F. S. Littauer, Rehovot.
 Professor S. Ravikovitch, Rehovot.
Jamaica : Professor G. F. Asprey, University College.
 Mr. P. D. Manser, Sugar Manufacturers' Association.
Kenya : Dr. R. H. Le Pelley, Scott Laboratories.
Madagascar : Monsieur Jacques Velly, Lac Alaotra.
Malaya : Mr. Lim Chee Poe, The University.
New Zealand : Dr. H. E. Annett, Hamilton.
 Mr. O. E. Clinton, Auckland.
 Dr. E. B. Davies, Hamilton.
 Mr. B. Healy, D.S.I.R., Wellington.
 Dr. Elsa B. Kidson, Cawthron Institute.
 Mr. D. J. Mackenzie, Nelson.
 Mr. and Mrs. A. C. McArthur, Auckland.
 Mr. D. W. McKenzie, Auckland.
 Mr. R. P. Rafferty, Auckland.
 Mr. D. Spiller, Hobart.
 Mr. J. A. Veale, Canterbury Agricultural College.
 Mr. B. B. Watts, Shell Company.
Nigeria : Professor H. C. Trumble, University College.
Norway : Miss Marie Bragdo, Vollebekk.
 Mr. A. Nordby, Vollebekk.
Pakistan : Mr. A. S. Islam, Dacca.
Phillippines : Mr. M. E. Lopez, Leyte.
 Mr. P. P. Namocale, Manila.
Sierra Leone : Mr. W. Jackson, Rokupr.
Solomon Islands : Mr. E. R. Brown, Agricultural Department.
South Africa : Mr. C. A. Cunningham, Grabouw.
 Mr. C. C. Hattingh, Pest Control.
 Dr. P. G. Marais, Stellenbosch.
 Dr. D. E. Roux, Natal.
Southern Rhodesia : Mr. G. A. Bates, Department of Agriculture.
 Mr. J. S. Cole, Tobacco Research Board.
 Mr. R. G. Skipwith, Umtali.
Sudan : Mr. H. A. Hashim, Gezira.
Sweden : Mr. T. Ingerstad, Stockholm.
 Dr. Lilihoek.
Tanganyika : Dr. E. C. Diekmahns.
 Dr. J. Robinson, Arusha.
Trinidad : Mr. R. S. Ayliffe, Forestry Department.
 Mr. R. Nichols, I.C.T.A.
Uganda : Mr. P. Huxley, Makerere College.
 Mr. T. R. Jones, Agricultural Department.
U.S.A. : Dr. G. B. Bodman, University of California, Berkeley.
 Professor and Mrs. J. P. Conrad, University of California, Davis.
 Mr. B. W. Drew, Massachusetts.
 Dr. A. B. Groves, Virginia.

Professor F. H. Lewis, Arendtsville, Pennsylvania.
 Mr. Mack, New Hampshire.
 Professor C. E. Marshall, University of Missouri.
 Miss H. H. Moreland, University of Boston, Massachusetts.
 Professor J. C. Moyer, N.Y.S. Experiment Station, Geneva.
 Dr. N. Polurin, Yale University, New Haven.
 Dr. W. Reuther, Orlando, Florida.
 Mr. G. Schriver, Bendersville, Pennsylvania.
 Dr. K. V. Thimann, Harvard University, Cambridge.
 Dr. C. Warren Shaw, Beltsville.
 Professor J. F. Wilson, University of California, Davis.
 Dr. O. J. Worthington, Oregon State College.
 Mr. A. Djikic, Sarajevo, Bosnia.
 Mr. S. Paunovic.

Yugoslavia :

Shows and Demonstrations.

Exhibits were staged at the following shows :—

Royal Horticultural Society, Chelsea, 25th–28th May.
Bath and West and Southern Counties Society, Exeter, 2nd–5th June.
Three Counties Show, Gloucester, 8th–10th June.
Royal Agricultural Show, Windsor, 6th–9th July.
Bristol Horticultural Show, Bristol, 1st–3rd September.

Students and Voluntary Workers.

The lack of laboratory accommodation continues to impose a limit on the number of students it is possible to take at the Station, but with the beginning of the Station building programme at hand it is hoped that this position will be remedied within the course of the next two or three years.

Mr. M. I. Candela Martinez of the Instituto de Edafologia y Fisiologia Vegetal, Madrid, who had spent two years at the Station from March 1952 to March 1954, returned to continue his studies on plant nutrition for the Ph.D. degree on 23rd July, 1954. He hopes to complete his investigations by 31st March, 1955.

Miss F. L. C. Blackwall continued her work in the Pomology Section, under a Ministry of Agriculture post-graduate scholarship in Husbandry, awarded for two years from 1st October, 1953.

Mr. J. M. Rayner continued his work in entomology under the Boots Scholarship, awarded to him for two years from 1st October, 1953.

Mr. Abdullah Djikic, an officer of the Yugoslavian Agricultural Advisory Service, worked at the Station for four months from 9th July in the Cider and Fruit Juices Section, under an arrangement of the Ministry of Agriculture with the Government of Yugoslavia.

Mr. E. Yanez of the Department of Agriculture, Bolivia, spent the period from 28th June to 9th July at the Station, during the tenure of a British Council Scholarship, to study propagation problems of tree fruits.

Cider Memorial Studentship. Mr. J. B. Howell completed his six months' training on 15th April, and Mr. R. G. Cove, also a nominee of Somerset County Council, began his period of training on 27th September.

Social Activities.

The Welfare Committee, under the chairmanship of Mr. J. G. Carr, as usual organised the Christmas Party in the Village Hall on the evening of December 22nd, when the staff entertainment took the form of a variety programme instead of the customary pantomime.

We were particularly fortunate to have the privilege of hearing a lecture on 8th April given by Mr. Michael Westmacott, a member of the staff of Rothamsted Experimental Station, on the Everest expedition in which he took part. His firsthand account and the beautiful coloured illustrations were greatly enjoyed and will long be remembered.

After completing the 1953/54 season in the local Church of England League, the Football Club changed over to the Bristol Downs League, Division IV, for the 1954/55 season. Lack of players resulted in a disappointing record, 7 games being won, 2 drawn and 17 lost.

The Cricket Club, however, received increased support and enjoyed one of its most successful seasons since the war. The Club was among the last sixteen in the Evening Post H.E.R. Cup and was defeated by the ultimate winners.

The Tennis Club suffered considerably from the very poor weather during the summer, and more than half of the friendly fixtures had to be cancelled. In the Bristol & District League, however, the Men's Team retained their position in Group 5, being placed 3rd.

Acknowledgments.

We would wish to record our grateful acknowledgments to those members of the Station staff who have carried out special duties during the year in addition to their normal work. Dr. Kearns has continued his much valued service in superintending the planning of new buildings and the work carried out in the Station workshops, including repairs to equipment, machinery and tools for laboratories and farm. Mr. Spinks has continued as Librarian. Mr. Carr was elected Chairman of the Welfare Committee this year, and in that capacity has been responsible for arranging the Christmas Party. Mrs. Pope relinquished the Chairmanship of the Canteen Committee on leaving the Station staff in September, after giving most valuable service to the canteen over the past two years. Mr. Burroughs succeeded her as Chairman of this committee, and we are grateful to him and to Miss Johnstone, Miss Locke and Miss Perkins, for the organization of canteen meals, and also of the Christmas Dinner which was much enjoyed again this year.

We should like here to express our gratitude to these and all other members of staff for their services to the Station during the year, and for the contribution each has made to the fulfilment of our research programme.

Our thanks are also due to our many friends outside the Station, particularly growers and commercial firms, for their help and co-operation in our work during the year.

THE PRODUCTION OF CIDER FRUIT ON BUSH TREES : OBSERVATIONS ON YIELDS AND ORCHARD BEHAVIOUR 1950-53.

FINAL REPORT.

By R. R. WILLIAMS.

Introduction.

Investigations at Long Ashton regarding the possibilities of growing bush cider trees resulted in the initiation of a cider bush plot trial scheme in 1930-31. It was hoped that the growing of bush trees under plantation conditions would meet the requirements for early and heavy cropping. A selection of vintage varieties was propagated and trial plots were established at Long Ashton and eight other centres.

Progress reports describing the sites, varieties, growth and cropping, have been given in the Station Annual Reports (1-4). During recent years actual crop weights were recorded at two of these centres, Hereford and Long Ashton. Visual estimates of yield have been obtained from five other centres.

The Long Ashton plot was used for nutrition experiments (5), but the crop weights, with those from the Hereford centre, are an indication of the yields which may be obtained given satisfactory management. Crop estimates from the other centres were provided by various people whose methods of assessment varied. These results are summarized in a list of the varieties showing successes and failures at the respective sites.

The orchards are now fully mature and the observations made indicate which varieties combine heavy crops with good orchard characteristics. The annual recording of crops has been discontinued but plots will be kept under observation and any outstanding development noted.

Cropping.

The conclusions from crop estimates are given in Table I. At centres in Worcestershire, Gloucestershire, Devon, Somerset and Herefordshire, the following varieties were satisfactory : Bulmer's Norman, Dabinett, Ellis Bitter, Perthyre, Reinette Obry, Stoke Red, Sweet Alford and Yarlington Mill. The failures were Cap of Liberty, Frederick, Improved Foxwhelp, Kingston Black, Knotted Kernel, Upright Médaille d'Or, Reine des Pommes, Silver Cup and Woodbine. The other varieties gave variable results.

A summary of crop weights obtained at Hereford is given in Table IIA. The two-year averages are given in Table IIB : these allow for the biennial habit of the heavy-cropping varieties. At Hereford, Bulmer's Norman, Dabinett, Michelin, Red Jersey, Sherrington Norman, Sweet Alford and Yarlington Mill were satisfactory. Failures included Kingston Black, Royal Wilding, Silver Cup, Tardive Forestier and Upright Médaille d'Or. Other varieties gave variable results.

The Long Ashton plot yields are summarised in Table III. Dabinett, Sweet Alford and Stoke Red have cropped heavily and consistently, but Knotted Kernel and Woodbine have not been satisfactory.

TABLE I.

CROPPING CAPACITY OF CIDER VARIETIES AT VARIOUS BUSH TRIAL CENTRES.

(Results from visual estimates).

Variety	Centres				Much Marele,* Hereford
	Newnham Bridge, Wores.	Compton Greenfield, Glos.	Whimple, Devon	Poundisford, Somerset	
Bulmer's Norman	Good	Good	Good	Fair	Good
Cap of Liberty ..	—	Poor	Poor	—	—
Chisel Jersey ..	—	Fair	—	Good	—
Dabinett ..	Good	Fair	Fair	Good	Poor
Dove ..	Poor	—	—	—	Fair
Dymock Red ..	—	Fair	—	—	Fair
Ellis Bitter ..	Good	Poor	Poor	—	Good
Fair Maid of Devon	—	—	Good	—	Good
Frederick ..	Fair	Poor	Fair	Poor	Poor
Improved Foxwhelp	Poor	—	Fair	—	Poor
Kingston Black ..	Fair	—	Poor	Poor	Poor
Knotted Kernel ..	Poor	Poor	Poor	—	Poor
Upright Médaille d'Or	Poor	Poor	Fair	Good	Poor
Michelin ..	—	—	—	Good	—
Perthre (Broadleaf Norman)	Good	—	—	Good	Poor
Red Jersey ..	Poor	—	—	Good	—
Reine des Pommes	Good	Poor	Poor	Poor	Fair
Reinette Obry ..	Good	Fair	Fair	—	Good
Royal Wilding ..	Fair	—	—	—	—
Sherrington Norman	—	—	Good	—	—
Silver Cup ..	Poor	Poor	Fair	Poor	Poor
Stack-ma-Girdle..	Poor	—	Fair	Fair	Good
Stoke Red ..	Good	Good	—	Fair	Good
Sweet Alford ..	Good	—	Fair	Good	Fair
Tardive Forestier	Fair	Poor	Fair	Poor	Good
White Close Pippin	Good	Fair	Good	—	Poor
White Jersey ..	—	—	—	—	Poor
White Norman ..	—	—	—	—	Poor
Woodbine ..	Fair	Poor	—	Poor	Fair
Yarlington Mill ..	Good	Good	Good	Fair	Good

*Actual crop weights were obtained from this centre for three years out of the four under review.

TABLE IIA.
(KING'S ACRE, HEREFORD, BUSH CIDER TRIAL).
SUMMARY OF CROP YIELDS 1950 TO 1953.
160 trees per acre.

Year	Variety	No. of trees	Yield cwt. lb.	Yield per tree cwt. lb.	Yield per acre tons cwt.
1950	Bulmer's Norman ..	10	—	—	—
	*Chisel Jersey	5	2 0	45	3 4
	Dabinett	10	2 0	22	1 12
	Ellis Bitter	10	1 28	14	1 0
	Foxwhelp	10	1 0	11	16
	Kingston Black	10	28	3	4
	Knotted Kernel	5	20	4	6
	Michelin	10	—	—	—
	Red Jersey	10	3 28	36	2 12
	Reine des Pommes ..	10	2 56	28	2 0
	Royal Wilding	5	2	0	0
	Sherrington Norman ..	10	17 84	1 87	14 4
	Silver Cup	10	6	1	1
	Spreading Médaille d'Or ..	10	2 0	22	1 12
	Sweet Alford	10	21	2	3
	Tardive Forestier	10	36	4	5
	White Close Pippin ..	10	70	7	10
	White Jersey	10	7 0	78	5 12
	Woodbine	5	—	—	—
	Yarlington Mill	9	—	—	—
	Upright Médaille d'Or ..	10	6 65	74	5 5
1951	Bulmer's Norman ..	10	20 84	2 8	16 12
	*Chisel Jersey	5	5 28	1 6	8 8
	Dabinett	10	19 84	1 109	15 16
	Ellis Bitter	10	17 56	1 84	14 0
	Foxwhelp	10	11 28	1 14	9 0
	Kingston Black	10	12 0	1 22	9 12
	Knotted Kernel	5	6 56	1 34	10 8
	Michelin	10	24 56	2 50	19 12
	Red Jersey	10	19 28	1 104	15 8
	Reine des Pommes ..	10	13 28	1 36	10 12
	Royal Wilding	5	1 84	39	2 16
	Sherrington Norman ..	10	10 56	1 6	8 8
	Silver Cup	10	7 56	84	6 0
	Spreading Médaille d'Or ..	10	18 84	1 98	15 0
	Sweet Alford	10	22 56	2 28	18 0
	Tardive Forestier	10	13 28	1 36	10 12
	White Close Pippin ..	10	18 28	1 92	14 12
	White Jersey	10	4 0	45	3 4
	Woodbine	5	9 0	1 90	14 8
	Yarlington Mill	9	19 56	2 19	17 7
	Upright Médaille d'Or ..	10	—	—	—

TABLE IIA—*continued*.
 (KING'S ACRE, HEREFORD, BUSH CIDER TRIAL).
 SUMMARY OF CROP YIELDS 1950 TO 1953.
 160 trees per acre.

Year	Variety	No. of trees	Yield cwt. lbs.	Yield per tree cwt. lbs.	Yield per acre tons cwt.
1952	Bulmer's Norman ..	10	—	—	—
	*Chisel Jersey	5	1 56	34	2 8
	Dabinett	10	4 28	48	3 8
	Ellis Bitter	10	20	2	3
	Foxwhelp	10	—	—	—
	Kingston Black	10	1 0	11	16
	Knotted Kernel	5	—	—	—
	Michelin	10	84	8	12
	Red Jersey	10	98	10	14
	Reine des Pommes ..	10	1 60	17	1 5
	Royal Wilding	5	—	—	—
	Sherrington Norman ..	10	16 103	1 78	13 11
	Silver Cup	10	—	—	—
	Spreading Médaille d'Or..	10	1 42	15	1 2
	Sweet Alford	10	1 69	18	1 6
	Tardive Forestier ..	10	—	—	—
	White Close Pippin ..	10	—	—	—
	White Jersey	10	11 68	1 18	9 6
	Woodbine	5	—	—	—
	Yarlington Mill	9	2 14	26	1 18
	Upright Médaille d'Or ..	10	10 0	1 0	8 0
1953	Bulmer's Norman ..	10	34 91	3 54	27 17
	*Chisel Jersey	5	6 85	1 39	10 16
	Dabinett	10	16 14	1 67	12 18
	Ellis Bitter	10	14 67	1 52	11 14
	Foxwhelp	10	27 0	2 78	21 12
	Kingston Black	10	6 14	69	4 18
	Knotted Kernel	5	8 30	1 73	13 5
	Michelin	10	34 92	3 54	27 17
	Red Jersey	10	22 99	2 32	18 6
	Reine des Pommes ..	10	11 8	1 12	8 17
	Royal Wilding	5	—	—	—
	Sherrington Norman ..	10	7 0	78	5 12
	Silver Cup	10	6 18	69	4 19
	Spreading Médaille d'Or..	10	15 63	1 62	12 9
	Sweet Alford	10	13 31	1 37	10 12
	Tardive Forestier ..	10	14 87	1 54	11 16
	White Close Pippin ..	10	17 23	1 81	13 15
	White Jersey	10	4 61	51	3 13
	White Jersey	5	8 85	1 84	14 0
	Woodbine	5	8 85	1 84	14 0
	Yarlington Mill	9	18 3	2 0	16 0
	Upright Médaille d'Or ..	10	3 36	37	2 13

*Chisel Jersey headworked in 1948 on Royal Wilding.

TABLE IIB.
(KING'S ACRE, HEREFORD, BUSH CIDER TRIAL).
CROP YIELD AVERAGES OVER TWO YEARS.
160 trees per acre.

Year	Variety	Yield per acre tons cwt.		Year	Variety	Yield per acre tons cwt.	
1950	Sherrington Norman ..	11	6	1952	Michelin	14	5
	Michelin	9	16		Bulmer's Norman ..	13	19
	Sweet Alford	9	2		Foxwhelp	10	16
	Red Jersey	9	0		Sherrington Norman	9	12
	Dabinett	8	9		Red Jersey	9	10
	Yarlington Mill ..	8	9		Yarlington Mill ..	8	19
	Bulmer's Norman ..	8	6		Dabinett	8	3
	Spreading Médaille d'Or	8	6		Woodbine	7	0
	White Close Pippin ..	7	11		White Close Pippin ..	6	18
	Ellis Bitter	7	10		Spreading Médaille d'Or	6	16
-	Woodbine	7	4	-	Knotted Kernel ..	6	12
1951	Reine des Pommes ..	6	6	1953	Chisel Jersey	6	12
	Chisel Jersey	5	16		White Jersey	6	10
	Tardive Forestier ..	5	9		Sweet Alford	5	19
	Knotted Kernel ..	5	7		Ellis Bitter	5	18
	Foxwhelp	4	18		Tardive Forestier ..	5	18
	Kingston Black ..	4	18		Upright Médaille d'Or..	5	7
	White Jersey	4	8		Reine des Pommes ..	5	1
	Silver Cup	3	1		Kingston Black ..	2	17
	Upright Médaille d'Or..	2	12		Silver Cup	2	9
	Royal Wilding ..	—	—		Royal Wilding ..	—	—

TABLE IIIA.
(LONG ASHTON BUSH CIDER TRIAL).
SUMMARY OF CROP YIELDS 1950-1953.

Year	Variety	No. of trees	Yield		Yield per tree		Yield per acre (109 trees per acre) tons cwt.	
			cwt.	lb.	cwt.	lb.	tons	cwt.
1950	Dabinett	216	146	65		76	3	14
	Sweet Alford ..	216	349	79	1	69	8	16
	Stoke Red	216	180	36		94	4	11
	Knotted Kernel ..	145	35	23		27	1	6
	Woodbine	71	29	61		47	2	6
1951	Dabinett	216	207	43		108	5	5
	Sweet Alford ..	216	216	45	1	0	5	9
	Stoke Red	216	607	58	2	91	15	7
	Knotted Kernel ..	145	157	29	1	9	5	18
	Woodbine	71	73	57	1	4	5	13
1951-1952 Orchard thinned by removing every other row.					(54 trees per acre)			
1952	Dabinett	108	59	12		61	1	9
	Sweet Alford ..	108	130	85	1	24	3	6
	Stoke Red	108	85	31		88	2	2
	Knotted Kernel ..	59	56	83		108	2	12
	Woodbine	49	19	12		44	1	1
1953	Dabinett	108	160	80	1	55	4	1
	Sweet Alford ..	108	206	61	1	102	5	3
	Stoke Red	108	247	71	2	33	6	4
	Knotted Kernel ..	59	100	20	1	78	4	12
	Woodbine	49	42	101		98	2	7

TABLE IIIB.
(LONG ASHTON BUSH CIDER TRIAL).
CROP YIELD AVERAGES OVER 2 YEARS.

Year	Variety	Yield per acre (109 trees per acre) tons cwt.		Year	Variety	Yield per acre (54 trees per acre) tons cwt.	
		tons	cwt.			tons	cwt.
1950	Stoke Red	9	19	1952	Sweet Alford ..	4	5
	Sweet Alford ..	7	3		Stoke Red	4	4
	Dabinett	4	10		Knotted Kernel ..	3	13
1951	Woodbine	4	0	1953	Dabinett	2	15
	Knotted Kernel ..	3	14		Woodbine	1	14

Orchard behaviour.

While cropping performance is the most important feature of a vintage cider variety, consideration must be given to other orchard characteristics. When selecting varieties from the heavy-cropping list, self sterility and value as a pollinator, vigour and harvesting season should be considered. It is also important to note that certain varieties whose cropping capacity is extremely good cannot be recommended for planting because of detrimental features such as liability to disease and nutritional deficiencies. The result of these observations is summarized in the Appendix.

Conclusion.

This series of cider variety trials has shown that a small number of vintage varieties can be relied upon to produce good bush trees with a heavy cropping potential in a reasonably short period. These trees are apparently successful under a very wide range of environment and management. Varieties in this group are Bulmer's Norman, Dabinett, Sweet Alford and Yarlington Mill. It should be noted, however, that Sweet Alford has been reported to be a failure on some light soils.

The following varieties were successful on the sites where they were grown : Chisel Jersey, Michelin, Reinette Obry and Sherrington Norman. Of the remainder a number have been moderately successful : Ellis Bitter, Perthyre (synonymous with the Broadleaf Norman in this trial), Red Jersey, Stoke Red and White Close Pippin.

It is not advisable to consider the following varieties for general planting : Cap of Liberty, Dove, Dymock Red, Fair Maid of Devon, Frederick, Improved Foxwhelp, Kingston Black, Knotted Kernel, Upright Médaille d'Or, Reine des Pommes, Royal Wilding, Silver Cup, Slack-ma-girdle, Tardive Forestier or Woodbine.

APPENDIX :

ORCHARD BEHAVIOUR.

Bulmer's Norman :	Very vigorous growth, narrow crotches easily split ; harvesting early mid-season ; fruit sometimes scabs badly. Early flowering, self-sterile, useless as pollinator.
Dabinett :	Very precocious, making a small tree ; sensitive to low potash ; harvesting late mid-season. Mid-late flowering, self-fertile, good pollinator.
Sweet Alford :	Vigorous growth ; sensitive to low magnesium ; harvesting mid-season. Flowering mid-season, self-sterile, good pollinator.
Yarlington Mill :	Vigorous growth ; harvesting late mid-season. Flowering mid-season, partially self-sterile, good pollinator.
Chisel Jersey :	Moderate growth ; harvesting mid-season. Flowering late, good pollinator.
Michelin :	Moderate growth, upright ; harvesting mid-season. Flowering mid-season, self-fertile, good pollinator.
Reinette Obry :	Vigorous growth ; may suffer from severe dieback ; harvesting mid-season. Flowering mid-season, self fertile, good pollinator.
Sherrington Norman :	Vigorous growth, a low, wide head ; harvesting mid-season. Flowering early, self-sterile, useless as pollinator.
Ellis Bitter :	Vigorous growth ; harvesting early mid-season, fruit prone to brown rot after falling. Flowering late, self-sterile, good pollinator.
Perthyre :	Moderate growth, long, drooping branches, prone to breakage ; sometimes severely cankered ; harvesting mid-season. Flowering late mid-season, self-sterile, useless as pollinator.
Red Jersey :	Vigorous growth ; harvesting late mid-season, fruit sometimes severely scabbed. Flowering late, good pollinator.

- Stoke Red : Slow growing ; harvesting mid-season, fruit rather small. Flowering late mid-season, partially self-fertile, good pollinator.
- White Close Pippin : Vigorous growth ; harvesting mid-season. Flowering early mid-season.

Acknowledgments.

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POLLINATION REQUIREMENTS OF CIDER APPLE VARIETIES: II. PROGRESS REPORT, 1954.

By R. R. WILLIAMS.

In a preliminary account (1) of an investigation into the pollination of cider apple varieties it was reported that about half of the more popular varieties tested had appeared completely self sterile but that those varieties producing good pollen had invariably proved to be good pollinators.

In 1953 and 1954 further work has been carried out, mainly with varieties predominant in new plantations, to try to find the reason for this high proportion of self sterile varieties. In part it could be attributed to the selection of triploid varieties, but the number of diploid varieties showing self sterility was nevertheless high. It was found during 1954 that some of these varieties failed to set even after cross pollination.

Method.

The pollination and the pollen germination tests were carried out by the method previously used (1). Most of the pollinations were made in the same orchard of standard trees, but in 1954 four-year-old trees in pots were also used and pollinated in a greenhouse.

To determine whether the many failures in self pollination previously obtained were the result of true incompatibility, in all the self pollinations made in 1954 some of the pollen was used to cross pollinate another variety : this checked the viability of the pollen under natural conditions and supplemented the usual laboratory test in artificial media. Flowers on trees used for self pollination trials were also cross pollinated, thus establishing whether the tree was able to set fruit ; further evidence of this ability was obtained by noting the results of open pollination.

Results.

Pollen viability.

The results of pollen viability tests on varieties not previously examined are summarized in Table I. Germination figures have been grouped as previously : Poor <30% ; Medium 30-70% ; Good >70%.

It was confirmed that Dabinett, Michelin, Sweet Coppin and Stoke Red may be self fertile. Yarlinton Mill, which had previously proved sterile, Dove, Frederick, Hangdown, Kingston Black, Reinette Obry and Tardive Forestier all produced 10% initial set or over when selfed.

Court Royal, Backwell Red and Sweet Alford again failed to set an appreciable number of fruits when self pollinated. A similar result was obtained when the following varieties were selfed : Bédan des Parties, Belle Norman, Ellis Bitter, Fréquin Audievre, Improved Foxwhelp, Langworthy and Tremlett's Bitter.

The experimental details of individual pollinations are to be found in the Appendix.

TABLE I.
POLLEN VIABILITY.

Variety	Germination	Variety	Germination
Atalia	Medium	Maréchal	Good
Australian Crab	Good	Miss Hardings	Good
A.103	Good	Néhou	Good
AW.27	Good	Pages Yellow	Good
Berkeley Pippin	Good	Peau de Blaireau	Good
Binet Rouge	Good	Pomme de Loudon	Good
Bramtot	Good	Ponsford	Poor
Brown Thorn	Poor	Rajo	Good
Brown's Apple	Good	Reine des Hâtives	Good
Cimetière	Good	Sealey's Variety	Good
Collington Big Bitters	Poor	Stembridge Jersey	Good
Cow Apple	Good	Thomas Hunt	Good
E. Vowles No. 14	Poor	Tanners	Poor
Grosse Launette	Good	Twistbody Jersey No. 2	Good
Lavignée	Good	White Close Pippin	Good
Malio	Good	White Fréquin	Good
Mannings Woodbine	Good		

Self pollinations, 1953.

Table II summarizes the data obtained.

TABLE II.
SELF POLLINATION TRIALS 1953.

Variety	Previous results	1953
Michelin	Self fertile	Self fertile
Hangdown	—	" "
Tardive Forestier	—	" "
Reinette Obry	—	" "
Dabinett	Self fertile	" "
Sweet Coppin	" "	" "
Yarlington Mill	Self sterile	" "
Frederick	—	" "
Kingston Black	—	" "
Dove	—	" "
Stoke Red.. .. .	Self fertile	" "
Court Royal	Self sterile	Self sterile
Fréquin Audievre	—	" "
Langworthy	—	" "
Sweet Alford	Self sterile	" "
Improved Foxwhelp	—	" "
Belle Norman	—	" "
Backwell Red	Self sterile	" "
Bédan des Partes	—	" "
Ellis Bitter	—	" "
Tremlett's Bitter.. .. .	—	" "

Self and cross pollinations, 1954.

The results of the extended trials undertaken in 1954 are given in Table III.

TABLE III.

Variety	Previous results	1954	Other observations
Fair Maid of Devon ..	—	Self fertile	Adequate set with open pollination
Dove	Self fertile	" "	"
Upright Médaille d'Or ..	—	" "	"
Ashton Brown Jersey ..	—	" "	"
Dabinett .. .	Self fertile	" "	"
Yarlington Mill .. .	" "	" "	"
Reinette Obry .. .	" "	" "	"
Kingston Black .. .	" "	" "	"
Tardive Forestier ..	" "	" "	"
Sweet Coppin .. .	" "	" "	"
Court Royal .. .	Self sterile	Self sterile	"
Crimson King .. .	" "	" "	"
Backwell Red .. .	" "	" "	"
Fréquin Audievre ..	" "	" "	"
Bulmer's Norman ..	" "	" "	"
Improved Foxwhelp ..	" "	" "	"
Kingston Bitter ..	" "	" "	"
Langworthy .. .	" "	" "	"
Sweet Alford .. .	" "	" "	Cross fertility very poor in some trees, poor set with open pollination.
White Jersey .. .	—	" "	Adequate set with open pollination.
Michelin .. .	Self fertile	Self & cross sterile (pot) Self sterile, cross fertile (standard)	No set with open pollination
Frederick .. .	Self fertile	Self & cross sterile (pot) Self fertile (standard)	
Bédan des Parties ..	Self sterile	Self & cross sterile (standard)	
Ellis Bitter .. .	Self sterile	Self & cross sterile (standard and pot)	
Tremlett's Bitter ..	Self sterile	Self & cross sterile	No set with open pollination
Morgan Sweet .. .	(triploid)	Self fertile	} Fruits found to be seedless at maturity. Average seed content of selfed fruits <1.
Sherrington Norman ..	(triploid)	Self fertile	

The varieties fall into three groups : the first consists of varieties that set an appreciable crop when selfed ; the second contains varieties that were apparently self sterile, whilst the third includes varieties that gave unexpected results, many appearing to be cross sterile.

Orchard observations are of interest in connection with some of these results. For instance, standard trees which proved cross sterile lost all their blossom at petal fall, which is considerably earlier than is usual when effective pollination has taken place. Tremlett's Bitter was a typical example and examination of some late flowers showed that the ovules had aborted at full bloom.

Standard trees of Sweet Alford all carried a heavy blossom but with open pollination some trees carried a very poor set of fruit, while others set a heavy crop. The results for Sweet Alford (see Appendix) are based on a tree of each type.

Seedless fruits on triploid and diploid varieties were common during 1954 and this explains the results obtained with Sherrington Norman and Morgan Sweet.

Observations from outside sources indicated that similar results would probably have been obtained from many other West Country orchards.

It is not possible at this stage to explain the anomalous results obtained in 1954, or to say how frequently a variety may behave as though cross sterile. There is evidence to suggest that the self and cross fertility potential of a variety can vary from season to season and it is apparent that self pollination results in one season cannot be considered conclusive.

For the present two recommendations can be made. When a new orchard is planned allowance should be made for the cross pollination of all varieties, as self pollination may not always yield a crop even if the variety is considered highly self fertile. Secondly, failure of trees to set fruit following a heavy blossom does not necessarily mean that a pollination agent was lacking or that weather conditions were unsuitable at flowering time. Such a result may be associated with a failure within the trees themselves.

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APPENDIX.

Varieties	Type of tree used	Flowers pollinated	Initial set	% initial set	Fruit matured	% fruit matured
1953—						
Backwell Red Selfed	standard	160	0	0	0	0
Backwell Red × Tardive Forestier	"	80	71	89	65	81
Backwell Red × Tremlett's Bitter	"	80	67	84	54	67
Bédan des Parties Selfed	"	200	0	0	0	0
Belle Norman Selfed	"	200	3	2	2	1
Court Royal Selfed	"	172	8	5	6	3
Court Royal × Tardive Forestier	"	164	13	8	13	8
Dabinett Selfed	"	208	88	42	26	13
Dove Selfed	"	208	37	18	21	10
Ellis Bitter Selfed	"	200	0	0	0	0
Frederick Selfed	"	208	51	25	32	15
Fréquin Audievre Selfed	"	200	11	6	4	1
Hangdown Selfed	"	200	114	57	65	33
Improved Foxwhelp Selfed	"	200	2	1	1	1
Kingston Black Selfed	"	212	48	23	32	15
Langworthy Selfed	"	180	7	4	4	2
Michelin Selfed	"	204	182	89	83	41
Reinette Obry Selfed	"	200	108	54	47	24
Stoke Red Selfed	"	200	29	15	16	8
Sweet Alford Selfed	"	212	7	3	5	2
Sweet Coppin Selfed	"	200	38	19	21	11
Tardive Forestier Selfed	"	196	104	53	50	26
Tardive Forestier × Upright Médaille d'Or ..	"	140	134	96	124	89
Tremlett's Bitter Selfed	"	200	0	0	0	0
Tremlett's Bitter × Tardive Forestier ..	"	164	121	74	73	45
Yarlington Mill Selfed	"	200	53	27	31	16
1954—						
Ashton Brown Jersey Selfed	pot	96	38	40	32	33
Ashton Brown Jersey × Upright Médaille d'Or	"	27	13	48	13	48
Backwell Red Selfed	"	127	10	8	2	2
(Yarlington Mill × Backwell Red)	"	31	14	45	11	35
Backwell Red Selfed	standard	80	12	15	3	4
Backwell Red × Tremlett's Bitter	"	80	59	74	34	43
Bulmer's Norman Selfed	pot	82	1	1	1	1
Bulmer's Norman × Dabinett	"	44	16	36	13	30

APPENDIX—continued.

Varieties	Type of tree used	Flowers pollinated	Initial set	% initial set	Fruit matured	% fruit matured
Bulmer's Norman Selfed	standard	76	5	7	0	0
Bulmer's Norman × Tardive Forestier ..	"	72	53	74	31	43
Bulmer's Norman × Tremlett's Bitter ..	"	72	67	93	43	60
Bédan des Partes Selfed	"	52	0	0	0	0
Bédan des Partes × Sweet Coppin	"	56	1	2	1	2
(Sweet Alford × Bédan des Partes)	"	80	14	17	14	17
Court Royal Selfed	"	132	8	6	0	0
Court Royal × Tremlett's Bitter	"	80	57	71	42	52
Crimson King Selfed	pot	64	4	6	4	6
Crimson King × Tremlett's Bitter	"	20	8	40	8	40
Dabinett Selfed	"	64	18	28	15	23
Dabinett × Langworthy	"	64	15	23	15	23
(Bulmer's Norman × Dabinett)	"	44	16	36	13	30
Dabinett Selfed	standard	128	15	12	14	11
Dabinett × Yarrington Mill	"	82	54	66	37	45
(Ellis Bitter × Dabinett)	"	68	0	0	0	0
Dove Selfed	pot	16	12	75	12	75
Dove × Sweet Coppin	"	12	2	17	2	17
Ellis Bitter Selfed	"	102	2	2	0	0
Ellis Bitter × Reinette Obry	"	34	2	6	1	3
Ellis Bitter Selfed	standard	68	0	0	0	0
Ellis Bitter × Michelin	"	84	0	0	0	0
Ellis Bitter × Dabinett	"	68	0	0	0	0
Ellis Bitter × Sweet Alford	"	76	0	0	0	0
Ellis Bitter × Sweet Coppin	"	52	0	0	0	0
(Sweet Alford × Ellis Bitter)	"	40	7	18	3	8
(White Jersey × Ellis Bitter)	"	48	—	—	21	44
Fair Maid of Devon Selfed	"	102	78	76	45	44
Fair Maid of Devon × Ellis Bitter)	"	80	73	91	46	57
(Kingston Bitter × Fair Maid of Devon) ..	"	20	9	45	7	35
Fréquin Audievre Selfed	"	92	5	5	3	2
Frederick Selfed	pot	76	0	0	0	0
Frederick × Michelin	"	28	1	4	0	0
Frederick Selfed	standard	72	31	43	21	29
Frederick × Improved Foxwhelp	"	80	51	64	37	46
(Improved Foxwhelp × Frederick)	"	82	38	46	17	21
Improved Foxwhelp Selfed	"	84	0	0	0	0
Improved Foxwhelp × Frederick	"	82	38	46	17	21
(Sweet Alford × Improved Foxwhelp)	"	84	58	69	39	46
Kingston Bitter Selfed	"	80	0	0	0	0
Kingston Bitter × Fair Maid of Devon ..	"	20	9	45	7	35
(Stoke Red × Kingston Bitter)	"	80	63	79	22	27
Kingston Black Selfed	pot	72	9	12	7	10
Kingston Black × Sweet Coppin	"	16	5	31	5	31
Langworthy Selfed	pot	12	0	0	0	0

APPENDIX—continued.

Varieties	Type of tree used	Flowers pollinated	Initial set	% initial set	Fruit matured	% fruit matured
Upright Médaille d'Or Selfed	"	96	45	47	41	43
Upright Médaille d'Or×Tremlett's Bitter ..	"	28	12	43	12	43
(Ashton Brown Jersey×Upright Médaille d'Or).. .. .	"	27	15	56	15	56
Michelin Selfed	"	88	2	2	0	0
Michelin×Sweet Coppin	"	24	0	0	0	0
(Frederick×Michelin)	"	28	1	3	0	0
Michelin Selfed	standard	120	3	3	3	3
Michelin×Red Norman	"	80	78	98	72	90
(Ellis Bitter×Michelin)	"	84	0	0	0	0
(Sweet Alford×Michelin)	"	52	11	21	5	10
Morgan Sweet Selfed	"	63	11	17	8	13
Morgan Sweet×Reine des Pommes ..	"	127	61	48	43	34
Reine des Pommes Selfed	"	68	2	3	0	0
Reine des Pommes×Sweet Alford	"	80	37	46	21	26
Reinette Obry Selfed	pot	76	16	21	16	21
Reinette Obry×Improved Foxwhelp ..	"	28	19	68	17	61
(Ellis Bitter×Reinette Obry).. .. .	"	34	2	6	1	3
Sherrington Norman Selfed	standard	84	23	27	21	25
Sherrington Norman×Tardive Forestier ..	"	80	34	43	34	43
Stoke Red Selfed	"	84	17	20	3	4
Stoke Red×Kingston Bitter.. .. .	"	80	63	79	22	28
Sweet Alford Selfed	pot	88	0	0	0	0
Sweet Alford×Kingston Bitter	pot	28	7	25	7	25
Sweet Alford Selfed	standard	52	0	0	0	0
Sweet Alford×Bédan des Partes	"	80	14	18	14	18
Sweet Alford×Dabinett	"	48	8	17	6	13
Sweet Alford×Ellis Bitter	"	40	7	18	8	7
Sweet Alford×Michelin	"	52	11	21	5	10
Sweet Alford×Belle Norman	"	44	0	0	0	0
(Reinne des Pommes×Sweet Alford)	"	80	37	46	21	26
Sweet Alford Selfed	"	84	0	0	0	0
Sweet Alford×Improved Foxwhelp	"	84	58	69	39	46
Sweet Alford×Yarlington Mill	"	180	145	81	30	17
(Ellis Bitter×Sweet Alford)	"	76	0	0	0	0
Sweet Coppin Selfed	pot	36	2	6	2	6
Sweet Coppin×Michelin	"	16	14	88	12	75
(Michelin×Sweet Coppin)	"	24	0	0	0	0
(Kingston Black×Sweet Coppin)	"	16	5	31	5	31
(Dove×Sweet Coppin)	"	12	2	17	2	17
Sweet Coppin Selfed	standard	84	17	20	5	6
Tardive Forestier Selfed	pot	140	16	11	16	11
Tardive Forestier Selfed	standard	84	34	40	27	32
(Tremlett's Bitter×Tardive Forestier) ..	"	80	1	1	1	1
(Bulmer's Norman×Tardive Forestier) ..	"	72	53	74	31	43
(Sherrington Norman×Tardive Forestier) ..	"	80	34	43	34	43
Tremlett's Bitter Selfed	"	88	0	0	0	0
Tremlett's Bitter×Tardive Forestier ..	"	80	1	1	1	1

APPENDIX—*continued.*

Varieties	Type of tree used	Flowers pollinated	Initial set	% initial set	Fruit matured	% fruit matured
(Bulmer's Norman × Tremlett's Bitter) ..	"	72	67	93	43	60
(Backwell Red × Tremlett's Bitter)	"	80	59	74	34	43
White Jersey Selfed	"	80	0	0	0	0
White Jersey × Fair Maid of Devon ..	"	36	—	—	24	67
White Jersey × Fréquin Audievre	"	40	—	—	18	45
White Jersey × Ellis Bitter	"	48	—	—	21	44
Yarlington Mill Selfed	pot	76	20	26	20	26
Yarlington Mill × Backwell Red	"	31	14	45	11	35
(Backwell Red × Yarlington Mill)	"	22	8	36	6	27
Yarlington Mill Selfed	standard	104	—	—	4	4
(Dabinett × Yarlington Mill)	"	82	54	66	37	45
(Sweet Alford × Yarlington Mill)	"	180	145	80	30	17

2:4:5-TP AS A FRUIT-RIPENING AGENT: II. APPLE var. WORCESTER PEARMAIN.

By D. L. ABBOTT.

Introduction.

A previous article (1) has described a trial in which α -(2:4:5-trichlorophenoxy)-propionic acid (2:4:5-TP) was applied to trees of Worcester Pearmain in an attempt to advance fruit maturity. Good results were obtained when treatment was given on 4th August and ripe fruit of high quality was harvested 12 days before the normal picking date. Although no damage was observed during the summer of 1953 when the trees were sprayed, the possibility existed that treatment might have caused some injury to the trees which would become apparent only during the following season. The trees were therefore kept under observation throughout 1954 when their performance was indeed found to have been adversely affected. An account of the type and extent of the damage follows.

The 1953 trial had indicated that the earliest ripening without sacrifice of quality was likely to result from spraying with 2:4:5-TP at 40 p.p.m. 6 weeks before the normal harvest date, and this treatment was applied to further trees in 1954 to confirm the ripening effect of the spray and to provide further data on residual effects. Details of this trial, and of a small experiment to determine the effect of local applications of 2:4:5-TP, are given.

Observations on the trees treated in 1953.

2:4:5-TP had been applied to whole trees at 30 and 50 p.p.m. on 15th July and 4th August 1953. These four treatments, together with unsprayed controls, were replicated four times amongst the 20 mature bush trees constituting the trial.

Tree growth during 1954.

Although no damage resulting from the sprays had been apparent up to and during the dormant period, it became clear soon after bud burst that some trees were abnormal in their growth and development. Many unopened flowers withered at all stages from mouse-ear to pink bud so that some flower clusters failed entirely to bear blossom and eventually abscised. Other clusters carried a reduced number of flowers and these were weak, with small floral parts and short stalks. Growth of the vegetative buds was sluggish and the few leaves that unfolded were small. An unusually large number of buds remained dormant and this resulted in long lengths of bare branch. The appearance of the trees at petal-fall is shown in Fig. 1 of Plate 1.

On 13th May the 20 trees were classified into two groups according to whether development was normal or as described above. The classification was based on a visual inspection, and no record of previous treatment was taken into the field.

As the season advanced, those trees which had exhibited poor and stunted growth in the spring slowly improved in health and, though little extension growth was made, leaf coverage steadily increased. Meanwhile the trees which

had earlier developed normally began to show differences in vigour so that when another classification was made on the 15th June, three groups were necessary to accommodate the main types of growth.

Thereafter variation between the trees continued to become more difficult to detect until by 11th August, when a third classification was made, the presence or absence of much extension growth was the only vegetative character upon which two groups of trees could be differentiated.

The spray treatment previously afforded to each tree was then referred to and the classifications of the trees, arranged by treatments, are given in Table I.

TABLE I.
CLASSIFICATION OF TREES.
(No. of trees per treatment falling in each growth category).

Treatment (concentration and date of application)	13th May		15th June			11th August	
	Development		Vigour of growth and leaf coverage			Extension growth	
	normal	abnormal	good	medium	poor	strong	weak
Control	4		4			3	1
30 p.p.m. 15th July ..	4		1	3		1	3
50 " " ..	4		2	2		2	2
30 " 4th August ..	1	3		1	3	1	3
50 " " ..	1	3		1	3	2	2

Fruit growth and cropping in 1954.

The first picking was commenced on 8th September. Records for each tree were made; total yields per tree when harvesting was completed on 21st September are shown in Table II.

TABLE II.
CROP RECORDS 1954.

Treatment (concentration and date of application)	Kg. fruit per tree				Total	% of control
Control	47	75	74	57	253	
30 p.p.m. 15th July ..	30	48	46	43	167	66
50 " " ..	31	50	34	90	205	81
30 " 4th August ..	23	10	19	17	69	27
50 " " ..	15	5	7	28	55	22

PLATE I



Fig. 1. Damage to trees of Worcester Pearmain following application of 2:4:5 TP in 1953
 Left : Sprayed at 50 p.p.m. on 4th August, 1953.
 Right : Unsprayed control.
 (Photographed 19th May, 1954).

Differences in yield were due to differences in fruit number, there being no appreciable variation in mean fruit weight between treatments. No residual effect upon fruit maturity was noticed nor was quality affected by previous treatment.

Conclusion.

It is clear from Tables I and II that some damage was suffered by the trees of all four spray treatments, but the degree of damage and reduction in cropping in this experiment is dependent upon the time of application rather than upon the concentration of the spray. Thus while the early treatment on 15th July reduced the following year's crop by approximately 25% the later treatment on the 4th August reduced the subsequent crop by as much as 75%. It was, however, treatment at the later date which gave the better ripening in the year of application.

1954 Trial.

Experimental.

A block of 12 mature bush trees of Worcester Pearmain, in two rows, was sprayed with 2:4:5-TP at 40 p.p.m. on 30th July; an aqueous spray was applied with a power sprayer and no wetting agent was used. A block of 11 similar trees was left unsprayed as controls and the two blocks were separated by two rows which served as a guard against spray drift.

Two fruits were subsequently picked at random from each tree at weekly intervals and tested for hardness of flesh by the pressure test previously described (1). The remainder of the fruit was harvested in accordance with normal commercial practice.

Results.

A colour difference between treated and control fruit was clearly apparent three weeks after application of the spray, and the flesh of treated fruits had become appreciably softer than that of control fruits by the fourth week after spraying (Table III). Ripening of the treated apples was even, enabling the

TABLE III.
HARDNESS OF FLESH.

Date	Pressure required to force plunger into flesh (lb.)	
	Treated (mean of 24 fruits)	Control (mean of 22 fruits)
4th August	28.7	28.5
11th " 	27.2	27.7
19th " 	25.9	25.5
26th " 	20.9	22.4
2nd September ..	17.8	21.7
14th " 	—	18.3

whole crop to be harvested on 2nd September. The control trees were picked over on 14th September and the rest of the crop was harvested on 22nd September. Thus not only was the treated fruit ready for harvest 16 days before the average control fruit, but the expense of a second picking was avoided.

The beneficial effect of 2:4:5-TP on fruit maturity has been confirmed by this trial, but further observations must be made during 1955 and it seems unlikely that the sprayed trees will escape the delayed injury already described. Indeed the tips of some vigorous shoots, particularly "water shoots" arising from the base of main limbs, had withered and were dying back by the end of the 1954 season.

Effect of local application of 2:4:5-TP.

Nothing is known concerning the path of entry or mode of action of 2:4:5-TP in ripening apple fruits. A small experiment was therefore carried out to determine whether fruit maturity is hastened as a result of (a) the direct entry of the chemical into the fruit, (b) entry through the leaves, or (c) a combination of both.

Experimental.

2:4:5-TP at 50 p.p.m. was applied to small branches of Worcester Pearmain by the following methods :—

Treatment 1. The fruits only were painted with the solution by means of a small camel hair brush.

„ 2. The fruits were covered with plastic sheeting and the branch was then sprayed with a small hand pump. The sheeting was removed as soon as the spray on the leaves was dry.

„ 3. The entire branch was sprayed with a small hand pump.

Teepol at 1 ml./litre of spray solution was used to ensure that the waxy skin of the fruits was thoroughly wetted. The treatments, applied on 5th August, were replicated 10 times, together with 10 unsprayed controls, amongst 40 uniform small branches of 12 bush trees.

Results.

The fruits were picked on 14th September and those from each treatment were bulked. Visual examination showed that apples from treatments 2 and 3 had reached a similar stage of maturity, being ripe and having a clear red flush on a yellow ground colour. Fruits from treatment 1 appeared similar to the controls, both showing only a little dull red on a green ground.

Twenty fruits from each treatment were then taken at random and subjected to the pressure test, the results of which confirmed the conclusion of the visual examination.

Treatment.	Pressure (lb.) (mean of 20 fruits).				
Control ..	..	..	..	..	19.0
1 (fruit treated)	..	..	..	..	18.2
2 (leaves treated)	..	..	..	..	15.7
3 (fruit and leaves treated)	..	..	..	..	16.0

Thus it appears that the foliage, rather than fruits, should be thoroughly wetted with 2:4:5-TP when this substance is used as a fruit-ripening spray.

Summary.

- (1) Considerable injury was observed in 1954 on trees of Worcester Pearmain sprayed with 2:4:5-TP in 1953. Foliage and blossom were so reduced that trees sprayed on 15th July yielded approximately 75% of the control crop and those sprayed on 4th August yielded only 25%.
- (2) Application of 2:4:5-TP at 40 p.p.m. on 30th July 1954 again hastened fruit maturity and made possible the harvest of good quality ripe apples 16 days before the normal picking date.
- (3) The local application of 2:4:5-TP has shown it to be effective as a fruit-ripening agent when sprayed on the leaves rather than on the fruit.

Acknowledgments.

Thanks are due to Mr. C. W. Harper for applying sprays to whole trees, and to Miss A. J. Beagles and Mr. P. S. Weaver for assistance in hand painting fruits.

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PERRY PEARS AND THEIR CHARACTERS: II.

By R. R. WILLIAMS.

In a previous article (1) thirteen varieties of perry pear found in the West Midlands were described and the terms used were defined. The present paper continues the series with descriptions and illustrations of a further eleven varieties of perry pear from Gloucestershire and Herefordshire.

The figures given with each description contain drawings of typical fruits in longitudinal section, together with a flattened spur leaf. The typical winter appearance of mature trees is illustrated by photographs.

Gin.

Fruit : 35-49 mm. long, 42-58 mm. diameter. Shape broadly turbinate, approaching oblate. Stalk 22-39 mm. ; slender. Stem basin absent or slight. Eye basin absent or slight. Calyx closed or slightly open. Sepals free ; stamens attached at base of sepals. Skin green, usually with an orange flush, sometimes faintly streaked ; russet restricted to a small area around stem and eye, lenticels small and inconspicuous ; scab absent. Core has filled axial sac ; seeds black when fruit is ripe. Flesh has some stone cells around core. Taste crisp, juicy, astringent ; possesses an aroma when ripe. Harvest 2nd-3rd week October. Milling period 3-5 weeks after harvesting. Cropping very good but often biennial.

Tree : Medium size. Narrow-angled crotches, limbs slightly spreading due to crops, heavy conspicuous spur systems.

Flower : Flowering period mid-season. Flower buds with a slight or strong pink flush. Styles slightly longer than stamens, usually bent. King flowers usually have more than 5 stigmas.

Leaf : Stalk 33-48 mm. Blade 64-78 mm. long, 38-50 mm. wide, elliptical ; tip acute, sometimes acuminate ; base rounded ; serrations present.

General notes : A local variety from the Newent district of Gloucestershire. The trees are large and healthy. The keeping quality of the fruit is a valuable attribute often lacking in perry pears.

Green Longdon.

SYN. OLD-FASHIONED LONGDON.

Fruit : 47-67 mm. long, 38-54 mm. diameter. Shape pyriform. Stalk 22-35 mm. ; usually swollen at union with fruit. Stem basin absent. Eye basin usually small, sometimes deep, rarely absent. Calyx slightly open or closed, pubescent, small. Sepals free ; stamens attached at base of sepals or a little below. Skin green or yellowish green ; flush dull red or reddish brown, rarely streaked ; russet spreading over cheek ; lenticels numerous, light brown, larger near stem, conspicuous on flush or russet ; scab present, sometimes severe. Core has no axial sac or only slight trace ; seeds dark-brown or black, usually few. Flesh has concentration of stone cells below eye and some around core, pronounced green tinge, especially under skin. Taste juicy, astringent ; possesses an aroma. Harvest 2nd-4th week October. Milling period up to 3 weeks after harvesting. Cropping irregular.

Tree : Medium size. The trunk is usually continued to a considerable height. Wide-angled crotches, numerous spurs.

Flower : Flowering period late mid-season. Inflorescence pubescent. Flower buds flushed. Styles shorter than stamens.

Leaf : Stalk 31–40 mm. Blade 46–56 mm. long, 31–43 mm. wide, obovate, tip acuminate, base rounded ; serrations sometimes present, irregular.

General notes : Widely grown in N.W. Gloucestershire. Frequently confused with Winnal's Longdon. The fruit is characterised by the ease with which it splits when hitting the ground although the flesh is hard. The variety is well known to local perry makers on account of the large clots precipitated in freshly extracted juice.

Hendre Huffcap.

Fruit : 46–54 mm. long, 43–50 mm. diameter. Shape elliptical, often irregular, with bulge at stem end. Stalk 17–28 mm. Stem basin absent. Eye basin absent, raised eye usual. Calyx upright. Sepals free, often with small swellings below or between sepals ; stamens attached well below base of sepals. Skin green, yellowish green or yellow, flush slight, orange ; russet around eye and stem ; lenticels numerous, small, inconspicuous except on russet ; scab rarely present. Core has axial sac large and well-defined, sometimes open to carpels ; seeds dark-brown. Flesh has concentration of stone cells around the eye cavity and a few around core. Taste juicy, sweet, slightly astringent, possesses an aroma. Harvest 1st–2nd week October. Milling period up to 2 weeks after harvesting. Cropping very heavy.

Tree : Large. Crotches wide-angled ; usually a small number of long, upright limbs. Branches drooping with numerous spurs.

Flower : Flowering period early mid-season. Flower buds flushed. Styles same length as stamens.

Leaf : Stalk 41–55 mm. Blade 58–70 mm. long, 29–37 mm. wide, obovate to elliptical, tip acuminate, rarely obtuse, base broadly rounded ; serrations always present.

General notes : A local variety from the Ledbury district only, possessing the attributes of a good orchard and vintage variety.

Holmer.

SYN. CLUSTER-TOP.

Fruit : 24–34 mm. long, 29–38 mm. diameter. Shape round or oblate. Stalk 13–25 mm. Stem basin usually small and deep, sometimes shallow. Eye basin slight or absent. Calyx strongly reflexed, rarely upright. Sepals tubular, rarely joined ; stamens attached at base of sepals. Skin yellow or greenish yellow ; flush absent or slight, often blotchy ; russet around eye and stem, sometimes spreading to cheeks ; lenticels very numerous, variable, may be small, inconspicuous or large, white, conspicuous ; scab invariably present. Core has axial sac usually filled ; seeds black. Flesh has concentration of stone cells below eye and few scattered stone cells around core, often slightly yellow. Taste juicy, sweet, astringent ; possesses an aroma. Harvest 4th week September–1st week October. Milling period up to 4 days after harvesting. Cropping light to moderate.

Tree : Large. Acute-angled crotches ; very tall limbs ; numerous branches forming a dense head.

Flower : Flowering period mid-season. Flower buds flushed. Styles same length as stamens. Flowers with six or more petals common, especially terminal flowers.

Leaf : Stalk 25–45 mm. Blade 43–58 mm. long, 32–42 mm. wide, elliptical, rarely approaching obovate ; tip acuminate, rarely obtuse ; base rounded or slightly cordate ; serrations usually present.

General notes : A variety recommended by T. A. Knight and named after the parish of Holmer near Hereford. It is now widely distributed through the West Midlands and has many local synonyms referring to its alleged diuretic and aperient properties. Cropping is often restricted to the younger upright growth in the tree tops, hence the synonym Cluster-top.

Knapper.

SYN. KNAP PEAR.

Fruit : 38–47 mm. long, 37–43 mm. diameter. Shape pyriform, sometimes turbinate. Stalk 14–21 mm. ; often green or yellow green. Stem basin absent or slight. Eye basin slight, wide and shallow. Calyx upright, rather long. Sepals free or touching ; stamens attached at base of sepals. Skin yellow or yellow green ; flush slight, mainly on russet around eye ; russet around eye spreading to cheeks, sometimes a little around stem ; lenticels numerous, off-white, sometimes very conspicuous, some scab usual. Core has a well defined axial sac ; seeds black. Flesh has a few scattered stone cells around core. Taste juicy, sweet, slightly astringent, possesses an aroma. Harvest 1st–2nd week September. Milling period up to 5 days after harvesting. Cropping moderate.

Tree : Large. Acute-angled crotches ; very tall branches forming a wide flat head.

Flower : Flowering period mid-season. Flower buds white. Styles much longer than stamens. Terminal flowers usually have 5–10 petals, 5–7 stigmas.

Leaf : Stalk 34–49 mm. Blade 47–56 mm. long, 31–41 mm. wide, elliptical, tip acute or acuminate, base rounded or cordate ; serrations present.

General notes : A local variety of north-west Gloucestershire, once very popular for an early-maturing Christmas perry. The fruits split on hitting the ground and this doubtless explains the name Knapper.

New Meadow.

Fruit : 34–56 mm. long, 32–49 mm. diameter. Shape pyriform or turbinate, very variable. Stalk 16–31 mm., slender, usually connected to the fruit by a prominent fleshy lip. Stem basin absent. Eye basin small, shallow or absent. Calyx reflexed or open. Sepals joined ; stamens attached at base of sepals. Skin green or yellowish green, flush sometimes present, orange-red ; russet complete or nearly so ; lenticels numerous, large, white, conspicuous ; scab usually severe. Core has axial sac, sometimes ill-defined ; seeds dark brown or black. Flesh has some stone cells around core. Taste juicy, sweet, little or no astringency, very pronounced pear flavour, possesses a strong aroma. Harvest 1st–4th week October. Milling period up to 3 weeks after harvesting. Cropping poor.

Tree : Medium to large. Wide-angled crotches, small number of large straggling limbs.

Flower : Flowering period mid-season. Flower buds have a slight flush. Styles longer than stamens. Flowers have a pleasant aroma, unlike most pear varieties.

Leaf : Stalk 34–43 mm. long. Blade 50–60 mm. long, 40–50 mm. wide, elliptical, rarely approaching obovate, tip shortly acuminate or obtuse, base cordate ; serrations absent or rarely a trace.

General notes : Scattered trees of this variety are quite common. It is not easy to describe, as the fruits vary over a wide range of size and shape. The pears ripen over a long period.

Sack.

Fruit : 31–48 mm. long, 38–44 mm. diameter. Shape oblate. Stalk 23–39 mm. Stem basin well-defined or slight. Eye basin well-defined or slight. Calyx reflexed. Sepals joined, rarely tubular, large ; stamens attached at base of sepals. Skin green or yellowish green, flush red, usually marked, sometimes slight ; russet spreading from eye, little or none at stem ; lenticels numerous, small, inconspicuous ; scab absent or slight. Core has axial sac well-defined or filled, short ; seeds black. Flesh has stone cells below eye and few scattered around core. Taste juicy, sweet, astringent ; possesses an aroma. Harvest 1st–2nd week October. Milling period up to 2 days after harvesting. Cropping heavy but biennial.

Tree : Medium to large. Sturdy upright limb system, numerous branches with characteristic very wide-angled crotches. Thick growth of twigs giving a dense head.

Flower : Flowering period mid-season. Flower buds have slight flush. Styles same length as stigmas.

Leaf : Stalk 38–55 mm. Blade 46–61 mm. long, 30–40 mm. wide, elliptical ; tip acuminate, sometimes obtuse ; base rounded, sometimes slightly cordate ; serrations absent or few and irregular.

General notes : A very old variety widely planted in the vicinity of Ross-on-Wye and Newent. Harvesting is difficult, as the leaves turn brown and fall with the pears ; also the fruit needs to be milled immediately after picking up.

Thorn.

Fruit : 42–64 mm. long, 40–54 mm. diameter. Shape pyriform, sometimes turbinate. Stalk 11–25 mm. Stem basin absent. Eye basin wide and shallow, rarely absent. Calyx stiff, upright. Sepals free, stamens attached at base of sepals. Skin yellow, flush absent ; russet around stem and eye spreading from eye over cheek ; lenticels numerous, not conspicuous except on russet ; trace of scab often present. Core usually has axial sac, ill-defined or small ; seeds dark-brown or black. Flesh has a few stone cells around core. Taste juicy, sweet, astringent ; possesses an aroma. Harvest 3rd–4th week September. Milling period up to 1 week after harvesting. Cropping heavy.

Tree : Small. Limbs and branches very stout with a stiff, upright habit. Conspicuous spurs.

Flower : Flowering period early mid-season. Flower buds white. Styles same length as stamens.

Leaf : Stalk 25–42 mm. Blade 56–83 mm. long, 39–53 mm. wide, elliptical, tip acuminate, rarely obtuse, base rounded ; serrations few and irregular.

General notes : A variety with a long history. Once widely used for dessert and culinary purposes but now considered too astringent and used solely for perry. The habit of the tree and its capacity to carry heavy crops has made it a popular variety with the growers. The perry can be of very good quality.

Turner's Barn.

Fruit : 32–42 mm. long, 39–52 mm. diameter. Shape oblate, rarely round. Stalk 29–45 mm. Stem basin well-defined, rarely slight. Eye basin well-defined, rarely slight. Calyx prominent, open or reflexed. Sepals joined or tubular, pubescent, on small fleshy protuberances ; stamens attached at base of sepals. Skin green or greenish yellow, sometimes blotchy ; flush usually heavy, sometimes slight, sometimes blotchy, orange-red ; russet spreading in patches over cheek, often inconspicuous ; lenticels small and numerous, rarely large and white ; scab absent or slight. Core has axial sac, often filled ; seeds black. Flesh has stone cells around core. Taste crisp, juicy, sweet, sometimes slightly astringent ; possesses an aroma. Harvest 2nd–4th week October. Milling period up to 3 weeks after harvesting. Cropping very heavy.

Tree : Medium size. Narrow-angled crotches ; numerous upright limbs. Branches fairly stout but twiggy, giving a dense head.

Flower : Flowering period mid-season. Flower buds slightly flushed. Styles longer than stamens.

Leaf : Stalk 30–42 mm. Blade 53–68 mm. long, 42–51 mm. wide, elliptical, tip acuminate or obtuse, base cordate ; serrations usually present.

General notes : Common in north-west Gloucestershire. Usually considered to be of high vintage quality. The rather upright growth is very suitable for a grass orchard grazed by cattle.

White Bache.

Fruit : 37–49 mm. long, 36–49 mm. diameter. Shape turbinate, sometimes pyriform. Stalk 20–28 mm., stout, sometimes fleshy, may be connected to fruit by fleshy lip. Stem basin absent. Eye basin slight or absent. Calyx reflexed. Sepals free or touching, often on small fleshy protuberances ; stamens attached at base of sepals. Skin light-green or yellow ; flush absent ; russet around stem and eye ; lenticels numerous, small and brown around eye, becoming fewer but larger towards stem ; scab usually present. Core has axial sac, large, sometimes partially filled ; seeds black. Flesh, tinged green especially under skin, has stone cells around core and also scattered stone cells except near skin. Taste juicy, sweet, slightly astringent, possesses an aroma. Harvest 2nd–3rd week October. Milling period up to 1 week after harvesting. Cropping light.

Tree : Large. Wide-angled crotches, spreading, frequently horizontal limbs. Dense, twiggy branches.

Flower : Flowering period mid-season. Flower buds slightly flushed. Styles longer than stamens.

Leaf : Stalk 26–40 mm. Blade 42–54 mm. long, 31–37 mm. wide, elliptical, tip acute or acuminate, base rounded ; serrations absent or indefinite.

General notes : Cooke (2) makes special note of the vintage quality of this variety. It is grown in the Kempley district of Gloucestershire. Fruit in any one year is usually confined to a few branches. This characteristic is always prominent as the light green colour of the fruit is conspicuous.

White Longdon.

Fruit : 45–63 mm. long, 45–61 mm. diameter. Shape pyriform, rarely turbinate. Stalk 7–15 mm. Stem basin small, narrow, deep. Eye basin usually well-defined. Calyx reflexed. Sepals free or joined ; stamens attached at base of sepals. Skin greenish yellow or green, flush red or orange ; russet around stem, more round eye, rarely spreading to cheek, lenticels numerous, often large, conspicuous ; scab usual, often severe. Core has axial sac well-defined, often open to carpels ; seeds black. Flesh has small ring of stone cells around core, sometimes pronounced. Taste juicy, sweet, slightly astringent, possesses an aroma. Harvest 1st–2nd week October. Milling 1–3 weeks after harvesting. Cropping fair.

Tree : Large. Trunk is usually continued to a considerable height. Sparse branches, often with numerous young, upright shoots.

Flower : Flowering period early mid-season. Flower buds white. Styles same length as stamens. Pollen germination very poor.

Leaf : Stalk 27–42 mm. Blade 50–56 mm. long, 34–45 mm. wide, elliptical, tip acuminate, base rounded, rarely tapering ; serrations small, irregular or absent.

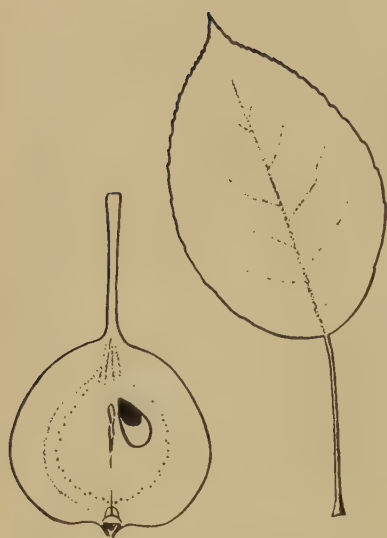
General notes : Scattered trees are to be found in most districts. It was propagated and distributed by Long Ashton 1907–1919 under the name Port. White Longlands, syn. White Horse Pear, as listed by Hogg and Bull (3), is known today as Horse or Green Horse while the name White Longdon appears to be restricted to the variety described above.

Acknowledgments.

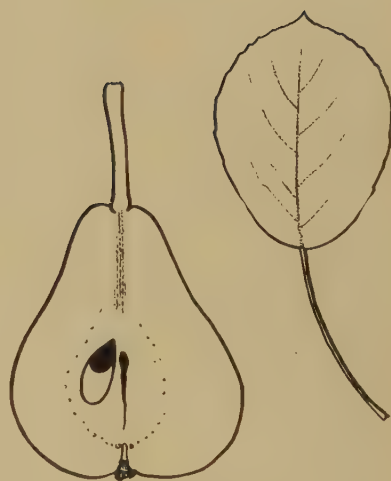
The author is indebted to the many farmers who have assisted in these investigations, and to Mr. G. H. Jones for the photographs.

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GIN.



GREEN LONGDON.



HENDRE HUFFCAP.



HOLMER.

Fig. 1.

PLATE II



GIN.



GREEN LONGDON.



HENDRE HUFFCAP.



HOLMER.

Fig. 2.

PLATE III.



KNAPPER.



NEW MEADOW.

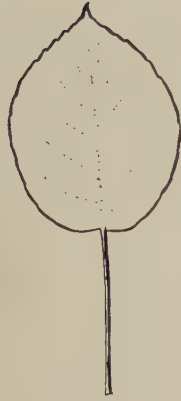
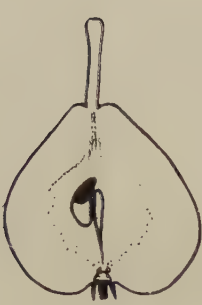


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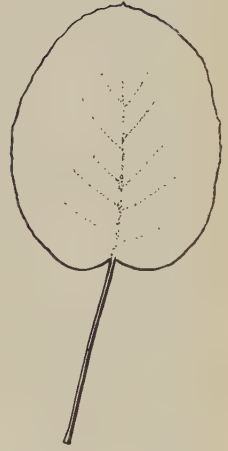


THORN.

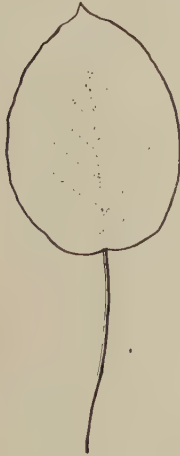
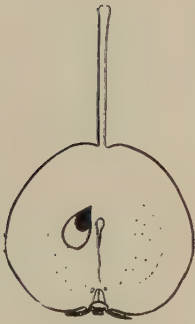
PLATE IV



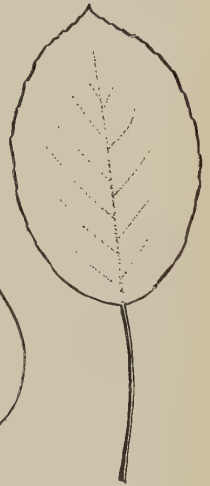
KNAPPER.



NEW MEADOW.



SACK.



THORN.

Fig. 4.

PLATE V



TURNER'S BARN.

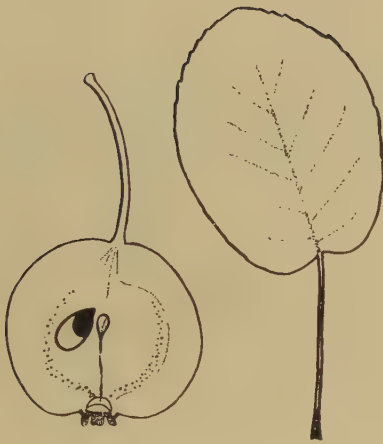


WHITE BACHE.

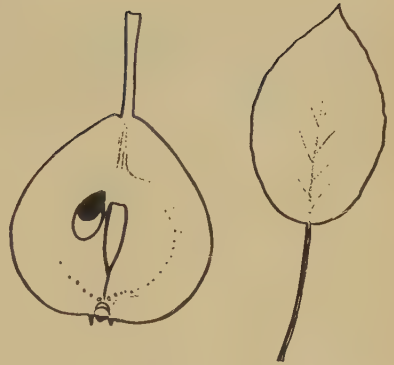


WHITE LONGDON.

Fig. 5.



TURNER'S BARN.



WHITE BACHE.



WHITE LONGDON.

Fig. 6.

ROOTSTOCKS SUITABLE FOR SOME NEW PLUM VARIETIES RAISED AT LONG ASHTON: NURSERY TRIALS.

By A. I. CAMPBELL.

Of the plum varieties raised at Long Ashton by G. T. Spinks four promise to become popular and are being planted in commercial orchards. These varieties are Teme Cross, Severn Cross, Frome Cross and Thames Cross (1, 2) of which Severn Cross received the Award of Merit after trial in the National Fruit Trials.

TABLE I.
ROOTSTOCKS BUDDED 1951: GRAFTED 1952.

Variety	Rootstock	Budded	Bud take	Grafted	Maiden trees
Teme Cross	Brompton	10	10	—	10
Severn Cross		10	10	—	10
Frome Cross		10	8	2	10
Thames Cross		10	6	4	10
Teme Cross	Common Mussel	10	5	5	8
Severn Cross		10	8	2	10
Frome Cross		10	9	1	8
Thames Cross		9	9	—	9
Teme Cross	Common Plum	10	5	5	2
Severn Cross		10	3	7	6
Frome Cross		10	—	10	—
Thames Cross		10	10	—	7
Teme Cross	Marianna	10	8	2	—
Severn Cross		10	9	1	—
Frome Cross		10	—	10	—
Thames Cross		10	10	—	10
Teme Cross	Myrobalan "B"	10	4	6	7
Severn Cross		10	9	1	9
Frome Cross		10	8	2	4
Thames Cross		10	9	1	10

The correct choice of rootstock for varieties of plum is essential for satisfactory growth and cropping, and it is advisable to try promising varieties on all the rootstocks likely to be used by nurserymen, who in latter years have reduced the number in general use to five or six.

The four new varieties were therefore tested on the following rootstocks :—Brompton, Common Mussel, Common Plum, Marianna and Myrobalan "B." The rootstocks were laid out in five blocks of forty and each variety was budded on ten rootstocks of each block in random order. When buds failed to grow stocks were grafted in the normal nursery manner using a whip and tongue graft. The results are shown in Table I.

Amos and others (3) and Chang (4) have shown that the percentage take of buds or grafts cannot always be accepted as a reliable indication of compatibility. It was decided that any doubtful combination of rootstock and scion variety should be repeated the following year: a combination that produced less than 70% of satisfactory maiden trees was therefore budded for a second time. The behaviour of the doubtful stock-scion combinations in the second test is shown in Table II.

TABLE II.
ROOTSTOCKS BUDDED 1953: GRAFTED 1954.

Variety	Rootstock	Budded	Bud take	Grafted	Maiden trees
Teme Cross	Common Plum	10	6	4	4
Severn Cross		10	10	—	10
Frome Cross		10	—	10	—
Teme Cross	Marianna	10	—	10	—
Severn Cross		10	—	10	—
Frome Cross		10	—	10	—
Frome Cross	Myrobalan "B"	10	10	—	6

From the results obtained it would seem that Brompton and Common Mussel make a satisfactory union with the four new varieties: this is as expected since these two rootstocks have so far been found compatible with all plum varieties. Myrobalan "B" gave doubtful results when worked with Frome Cross: the combination seemed variable and many of the unions were weak, suggesting that the tree might break down at a later stage. Common Plum also appeared to be completely incompatible with Frome Cross, while Teme Cross was very variable on this stock.

Marianna seems quite unsuited for Teme Cross, Severn Cross and Frome Cross: all three varieties failed completely in both experiments. On the other hand Thames Cross produced strong trees on Marianna, but it was noted that

all the trees had severe ringspot virus symptoms on the leaves of the scion although neither the rootstocks nor the parent budding material showed any symptoms of this disease.

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THE PROPAGATION OF GOOSEBERRIES :

II. THE INFLUENCE OF BASAL WOUNDING AND SIZE OF SHOOT ON THE ROOTING OF HARDWOOD CUTTINGS.

By BARBARA A. RAKE.

Introduction.

The preparation of hardwood cuttings involves a certain amount of wounding of the base. Oldham (1) has recommended that in the preparation of hardwood cuttings of gooseberries the amount of wounding should be kept to a minimum by using a sharp knife. On the other hand Woycicki (2) improved the rooting of carnation cuttings by slitting the stem from the base upwards for 1" ; and Stewart and Marth (3), working with holly, which normally produces roots on the base, were also able to increase the number of roots by basal splitting of the cutting. It appeared from Day's experiments (4) that the increased rooting of wounded cuttings is due to the increased uptake of water at the wounded surface.

In experiments made in 1953 with hardwood cuttings of gooseberries, two treatments—splitting the base of the stem and hammering the base of the stem—often used to increase water uptake of woody ornamentals when cut to stand in water, were included in addition to treatments comparing the rooting of cuttings prepared with a knife or with secateurs. It was thought that the use of secateurs, besides saving time, might by their slight bruising effect stimulate more basal roots to develop.

The effect of shoot length on rooting was investigated at the same time. The size of gooseberry cuttings is often governed by the material available, though various recommendations have been made. At the beginning of the century, Wright (5) recommended cuttings 10"–12" long, planted with only 4" below ground level ; while Thompson (6) recommended cuttings not less than 12" long and not more than 14" when prepared, planted with 6" of clean stem between the lowest bud and the soil. Recently it has been advised (7) to use cuttings at least 10" and preferably 12" long after preparation, and planted up to the lowest bud left towards the apex of the shoot. Oldham (1) recommended a length of 12"–14", planted with 3" of the shoot above the soil level. Four lengths ranging from 9"–18" were included in the present experiments.

Experimental.

The experiment was planned on a 4×4 factorial layout, randomised in five blocks, using three varieties (Leveller, Keepsake and Careless), giving a total of 240 plots. Each plot consisted of a row of 12 cuttings planted 6" apart ; the two end cuttings in each plot were guards and were not recorded.

The 16 treatments were given by the combination of the following wounding methods and lengths :—

Wounding Treatments.

- (1) Basal cut made with a sharp knife.
- (2) Basal cut made with Rolcut secateurs.
- (3) Basal $\frac{1}{4}$ " of cutting hammered.
- (4) Basal cut made with a sharp knife with a single split 1" from the base upwards.

Lengths (1) 9" ; (2) 12" ; (3) 15" ; (4) 18".

Owing to shortage of material it was necessary to prepare each length of cutting from a proportionate length of shoot : consequently the shoot girth varied according to the shoot length in the following way.

DIAMETER OF CUTTINGS (mm.).

Length Shoot (approx.)	11-12"		14-15"		17-18"		20-21"	
Length prepared cutting	9"		12"		15"		18"	
Variety	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Leveller	3.7	3.5-4.1	4.4	3.9-5.2	5.1	4.6-6.6	6.1	5.5-7.9
Keepsake	3.8	3.5-4.1	4.4	3.9-5.2	5.0	4.6-6.6	6.4	5.5-7.8
Careless	4.3	3.4-5.7	5.1	4.3-6.7	6.8	5.8-7.9	8.2	6.1-9.5

The cuttings were prepared by removing the lower buds from shoots cut to the correct length, leaving four or five buds at the top of the cutting. They were planted during the last week of September 1953 : all treatments were planted with the basal 9" of the cutting below ground with the exception of the cuttings 9" long, which were planted with the lowest of the remaining buds just above soil level (approx. 7" of cutting below ground).

At the end of the following August, when growth had ceased, records were made of the percentage rooting, and "vigour" was scored visually in categories 1-10 (1 indicated cuttings that were still alive but had made no growth).

Angular transformation was carried out on the results before analysis of variance.

Results.

Tables I-III show the percentage rooting and vigour of each variety, the effect of wounding and the effect of length respectively. Owing to the fact that the analyses were carried out on transformed figures the significance levels refer to these and not to the figures in the tables.

TABLE I.
THE ROOTING OF GOOSEBERRY VARIETIES 1953.
(Means based on 80 plots).

Variety	Mean percentage rooting	Mean score for vigour. (Max. 10)
Leveller ..	59.4	5.9
Keepsake ..	77.6	5.3
Careless ..	62.4	3.3

Percentage rooting : Keepsake > Leveller and Careless at 0.1%.
Leveller and Careless not significantly different.
Vigour : Leveller and Keepsake > Careless at 0.1%.

Variety (Table I).

In contrast to the findings of the two previous years (8) the variety Keepsake gave significantly better results for percentage rooting than the other two varieties. Leveller, which in 1951 and 1952 had given very low scores for vigour, had the highest score in 1953 though it was not significantly different from Keepsake. This is unusual, as Leveller is often considered a difficult variety on account of its poor growth in the cutting bed; as the cuttings were taken from the same source bushes in all three experiments, this seasonal difference is hard to explain.

TABLE II.
THE EFFECT OF WOUNDING THE BASE ON THE ROOTING OF GOOSEBERRY CUTTINGS.
(Means based on 60 plots).

Wounding	Mean percentage rooting	Mean score for vigour. (Max. 10)
Knife	70.7	5.4
Secateurs ..	76.0	5.1
Hammered ..	42.7	3.9
Split	76.5	4.9

Percentage rooting : Secateurs and splitting not significantly different.
Knife < secateurs and splitting at 5%.
Hammering < others at 0.1%.
Vigour : Knife, secateurs and splitting not significantly different among themselves.
Hammering < splitting at 5%, < secateurs at 1%, < knife at 0.1%.

Wounding (Table II).

Wounding the base of the stem by hammering had a definitely detrimental effect on rooting and subsequent growth. The other three wounding treatments varied very little; secateurs had no damaging effect and their use is considerably faster (and less painful) than a knife for most operators. Basal splitting did not justify the extra labour involved.

TABLE III.
THE EFFECT OF LENGTH ON THE ROOTING OF GOOSEBERRY CUTTINGS.
(Means based on 60 plots).

Length	Mean percentage rooting	Mean score for vigour. (Max. 10)
9"	71.2	4.6
12"	75.0	5.6
15"	66.0	4.8
18"	53.7	4.3

Percentage rooting: 9" and 12" not significantly different.

9" and 15" not significantly different.

12" > 15" at 1%. All others > 18" at 0.1%.

Vigour:

9", 15" and 18" not significantly different among themselves.

12" > 15" at 5%.

12" > 9" at 1%.

12" > 18" at 0.1%.

Length (Table III).

Satisfactory rooting was obtained from all lengths tried, with the exception of 18". It appeared that this factor is not very important, but when taking the figures for vigour into account, 12" gave the most satisfactory results.

Interactions (Table IV).

A significant three-factor interaction between variety, length and wounding showed up in the figures for percentage rooting. A table of "expected" values for the three main factors was constructed and the following differences were observed.

Leveller and Keepsake at 9" both showed poorer rooting than expectation for hammering (significant at 1%). Leveller at 12" showed higher results than expectation for all wounding treatments except hammering. Leveller at 15" showed a very low result for secateurs (significant at 1%) which is difficult to account for.

Keepsake at 12" showed lower results than expectation for all wounding treatments.

TABLE IV.
PERCENTAGE ROOTING OF CUTTINGS OF DIFFERENT VARIETIES HAVING DIFFERENT LENGTHS AND WOUNDING TREATMENTS.
(Means based on 5 plots).

Length ..	9"				12"				15"				18"			
	Knife	Secateurs	Hammered	Split	Knife	Secateurs	Hammered	Split	Knife	Secateurs	Hammered	Split	Knife	Secateurs	Hammered	Split
Wounding.. Variety																
Leveller ..	74.0	64.0	14.0	72.0	92.0	98.0	42.0	92.0	66.0	34.0	44.0	86.0	66.0	50.0	26.0	30.0
Keepsake ..	92.0	92.0	54.0	88.0	76.0	88.0	64.0	90.0	86.0	84.0	58.0	94.0	78.0	82.0	52.0	64.0
Careless ..	66.0	88.0	64.0	86.0	86.0	92.0	28.0	52.0	36.0	86.0	34.0	84.0	30.0	54.0	32.0	80.0

Careless at 12" showed a lower than expected result for splitting (significant at 1%) and at 15" and 18" cutting with a knife also showed lower results than would be expected.

The effect of hammering shows up more on the shorter lengths of cutting in Leveller and Keepsake probably because the longer lengths still have plenty of rooting surface after allowing for the damage caused. Careless does not show this effect significantly, possibly on account of the stouter shoots used for cuttings of this variety.

Summary.

An experiment to test the effect of four different lengths and four wounding treatments on the rooting of hardwood cuttings of three varieties of gooseberries is described.

Cuttings prepared with Rolcut secateurs rooted just as satisfactorily as those prepared with a knife. Neither splitting nor hammering the base of the cutting before insertion improved rooting.

Cuttings between 9" and 15" in length rooted well; the highest number of vigorous plants was obtained from cuttings 12" in length.

Acknowledgment.

Very grateful thanks are due to Mr. G. M. Clarke for carrying out the statistical analyses.

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A FAILURE IN APPLE TREES ON A STRONGLY ACID SOIL.

By C. BOULD and E. G. BRADFIELD.

In 1953 we were asked to investigate a suspected boron deficiency in a commercial orchard of Cox's Orange Pippin pyramid trees. Young trees in the affected area failed to become established, and developed die-back and some characteristic leaf and bark symptoms, the bark in particular showing a pimpled appearance suggestive of "bark measles," a disorder associated with boron deficiency in apples. The results of soil, leaf and bark analyses, and the lack of response to boron treatment, have indicated that the effects are not due to boron deficiency. The evidence points to soil acidity as the primary cause, with excess manganese as a possible contributing factor. Previous work at Long Ashton with vegetable crops has shown that acidity effects may include deficiencies of nitrogen, phosphorus, potassium, calcium, magnesium and molybdenum and excesses of manganese and aluminium.

Experimental.

The orchard was first visited on June 4th, 1953, when soil samples were taken from the affected area, and boron treatments were applied to the soil and trees. The orchard was visited again on August 20th, 1953, when leaf samples were taken for chemical analysis, and soil dressings of magnesian limestone were given to half of each plot previously treated with boron. Details of soil, symptoms, and treatments are given below together with analytical results.

Soil. The soil is a light acid gravel with a low base-exchange capacity. Samples for chemical analysis were taken at 0-6" and 6-12" from the affected area. The results are given in Table I.

TABLE I.
ANALYSIS OF SURFACE AND SUB-SOIL: AFFECTED AREA.
(Data for air-dry soil passing 2 mm. sieve).

Sampling depth	pH Soil:water 1:2.5	Exchange capacity m. eq. per 100 g. soil	Exchangeable Calcium per cent.	Exchangeable Manganese p.p.m.	Hot water- soluble Boron p.p.m.
0-6" ..	3.9	10.6	0.011	18.1	2.3
6-12" ..	4.2	10.2	0.024	4.5	3.7

Trees. The trees, *var.* Cox's Orange Pippin, are on Malling No. II root-stocks and vary in age from 2 to 9 years. In the experimental area about half are original trees and the remainder are replants of different ages.

Symptoms. In the severely affected area many trees have failed to become established. Extension growth ranges from nil to slight and new growths die back during the winter. On severely affected trees the leaves are small and brittle, with a tendency for the margins to curl towards the upper surface, and they show a moderate amount of intervenal chlorosis and necrosis. The fruit is very small, russeted and cracked at the calyx end. The bark shows characteristic pimpling but there is no apparent necrosis of the conducting tissue. Root growth is poor. Severely affected trees die after two or three seasons. Less severely affected trees show only mild pimpling of the bark and symptoms of magnesium deficiency in the leaf; the fruit is normal in appearance. Severely affected young trees are shown in Plate VI, Fig. 1 (a) and (b).

Soil and Foliage Treatments. On June 4th, 1953, an area on which some very severely affected trees occurred was marked out, and the following treatments were applied, in duplicate, to groups of 20 trees.

1. Control—no borax.
2. Soil dressings of borax at the rate of 20 lb. per acre.
3. One foliage spray of 0.1% borax + wetter.
4. One foliage spray of 0.2% borax + wetter.

After the soil samples had been analysed it seemed that soil acidity might be the primary cause of the disorder. The boron plots were therefore split, one half of each plot receiving a soil dressing of magnesian limestone at the rate of 2 tons per acre; this was applied on August 20th, 1953. Prior to the application of limestone, leaf samples for chemical analysis were taken from the boron-treated trees and also from good and severely affected neighbouring trees.

Results.

Soil. The analytical results for surface soil and for sub-soil are given in Table I. It will be seen that the surface soil is strongly acid and that the acidity decreases with depth; this is accompanied by a twofold increase in exchangeable calcium and a fourfold decrease in exchangeable manganese. The water-soluble boron content (2.3–3.7 p.p.m.) is considerably higher than the level of 0.5 p.p.m. considered to be adequate for normal growth, and is also higher than that found in two neighbouring fields where tree growth is satisfactory (0.5 and 0.7 p.p.m. water-soluble boron respectively).

Leaf and bark samples. The analytical results for leaves taken from severely affected trees, and from trees showing only mild bark pimpling, are given in Table II.

TABLE II.
CHEMICAL COMPOSITION OF UNTREATED LEAVES.
Sampled 20/8/53.

Sample from	Per cent. leaf dry matter				p.p.m. leaf dry matter	
	K	Ca	Mg	P	Mn	B
Severely affected trees . .	2.84	1.42	0.16	0.12	575	26
Mildly affected trees . .	2.79	0.98	0.22	0.20	195	25

PLATE VI



Fig. 1.



The main features are the low magnesium and phosphorus contents and the high manganese content of the leaves taken from the severely affected trees. The boron status of both leaf samples is satisfactory.

The analytical results for leaves taken from affected trees after treatment with boron are given in Table III. Treatment had relatively little effect on the boron status.

TABLE III.
MANGANESE AND BORON STATUS OF APPLE LEAVES.
Sampled 20/8/53.
(Results expressed as p.p.m. in dry matter).

	Treatment			
	20 lb. borax p.a. soil dressing	0.1% borax foliage spray	0.2% borax foliage spray	Control— no borax
Manganese ..	501	470	440	490
Boron ..	25	30	28	28

The analytical results for leaf samples taken in 1954, from trees treated with borax and limestone in 1953, are given in Table IV. It will be seen that the limestone had little effect on the leaf magnesium content. The differences in manganese content are probably due to differences in tree growth on the various plots rather than to treatment. Unless limestone is mixed thoroughly with the soil it is known to be slow acting, and affected trees have considerable reserves of manganese in the bark which would maintain a high status in the leaf, particularly under conditions of restricted extension growth.

TABLE IV.
MANGANESE AND MAGNESIUM STATUS OF APPLE LEAVES.
Sampled 10/9/54.
(Data on a dry matter basis).

Treatment 1953	p.p.m. Mn	% Mg
No borax, no limestone	760	0.13
No „ + „ 2 tons p.a.	470	0.10
0.1% borax spray no limestone	670	0.10
„ „ „ + „	405	0.13
0.2% borax spray no limestone	430	0.17
„ „ „ + „	480	0.14
20 lb. p.a. borax no limestone	520	0.13
„ „ „ + „	640	0.11

The manganese and molybdenum concentrations in bark from moderately affected and normal trees, and the molybdenum concentration in leaves from similar trees are given in Table V. The manganese content of bark from affected trees is approximately sixteen times greater than the manganese content of bark from normal trees, whereas the molybdenum status is approximately one half that of normal bark. Similarly the molybdenum status of leaves from affected trees is approximately one half that of leaves from normal trees.

TABLE V.
MANGANESE AND MOLYBDENUM STATUS OF BARK AND LEAVES.
Sampled 22/10/54.
(Data on a dry matter basis).

Trees	Bark		Leaves
	p.p.m. Mn	p.p.m. Mo	p.p.m. Mo
Moderately affected	345	0.28	0.13
Normal (Long Ashton)	22	0.60	0.27

Discussion.

The results of soil, leaf and bark analyses indicate that the condition of the apple trees is not due to a deficiency of boron but is associated with strongly acid conditions, the composition of leaves and bark of severely affected trees showing typical features of acid-soil plants. The magnesium status of the leaves is low (normal value = 0.25% Mg): this may be the result of heavy potassic manuring, for the potassium level in the leaves is high (normal value = 1.5% K). Magnesium deficiency is, however, unlikely to be the cause of the bark symptoms. The phosphorus status is also low (normal value = 0.25% P) but bark pimpling has never been apparent in phosphorus deficient trees grown in sand culture. The manganese contents of leaf and bark are abnormally high (normal value = 50 p.p.m. Mn) but there is no evidence that they are directly responsible for leaf and bark symptoms; and while the molybdenum levels in leaves and bark of affected trees are only half those of normal trees, they are nevertheless considerably higher than the recognised deficiency levels for citrus and vegetable crops (0.05 p.p.m. Mo).

Although the severely affected trees showed little growth and nutritional response to soil dressings of magnesian limestone during the first season, many of the severely affected young trees not receiving limestone died during the winter. It is doubtful whether severely affected trees will make normal growth until some years after treatment with surface dressings of limestone. It is suggested that the best procedure would consist in removing the severely affected young trees, thoroughly incorporating sufficient magnesian limestone to raise the soil pH to approximately 6.0, and re-planting with healthy trees.

Summary.

A soil condition causing restricted leaf and shoot growth, die-back and bark pimpling in pyramid apple trees has been investigated and shown to be associated with soil acidity. Leaves and bark from severely affected trees contained high concentrations of manganese and low levels of molybdenum, typical of plants from strongly acid soils.

THE FUNGICIDAL PROPERTIES OF COAL TAR DISTILLATES: PROGRESS REPORT II.

By G. V. COLES, J. T. MARTIN and R. J. W. BYRDE.

Introduction.

The first report (1) described investigations of the fungicidal efficiencies of components of coal tar distillates against *Ceratostomella fimbriata* (Ell. and Halst.), Elliot, the fungus responsible for the mouldy rot infection of the newly-tapped bark of the rubber tree. Information was given in the report on the extent to which the fungicidal activities of acidic and neutral tar oil fractions were influenced by boiling range and by the types of tar from which they had been prepared. Maximum efficiency against the fungus was associated with the high boiling tar acids (220°C. and above), and it seemed probable that the effect obtained was largely independent of their source. The fungicidal activities of the neutral tar oils, on the other hand, varied according to the method of production of the parent tars, the potencies of the high boiling neutral oils increasing as the carbonization processes became more severe. The tar bases also showed fungicidal activity.

The biological tests were made with tar fractions of known origin and characteristics obtained through the courtesy of the Coal Tar Research Association or from tar distillers, and with fractions separated in the laboratory from commercially-available tar oil fungicides. The experience gained in resolving the proprietary materials into their component parts has led to the development of an alternative method for the analysis of tar oil fungicides which is described briefly in this report. The method has been given in more detail elsewhere (2). An examination is also made of the extent to which the results of the chemical analysis of proprietary materials may be used to assess their biological performance in the field.

Chemical Tests.

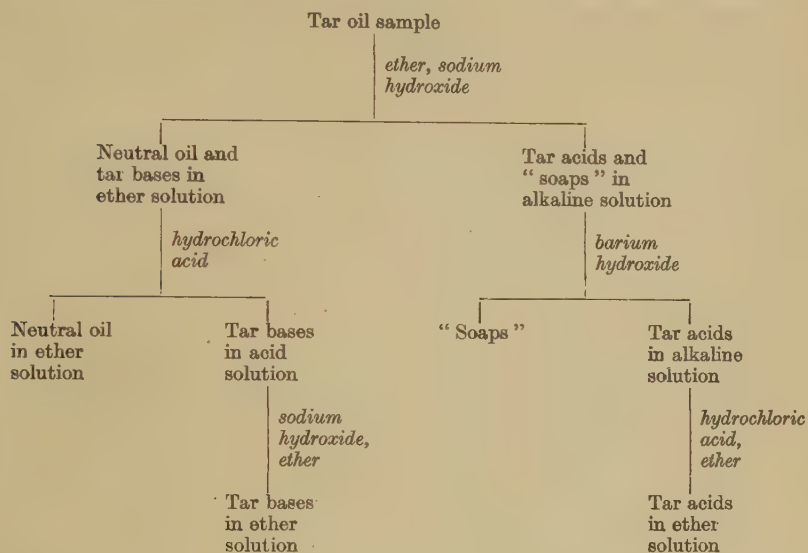
(a) *Method of winter wash analysis.*

The fractionation of the proprietary fungicides was first carried out using modifications of the standard method for the analysis of tar oil winter washes (3). The procedure used in the method is as follows:—(see next page).

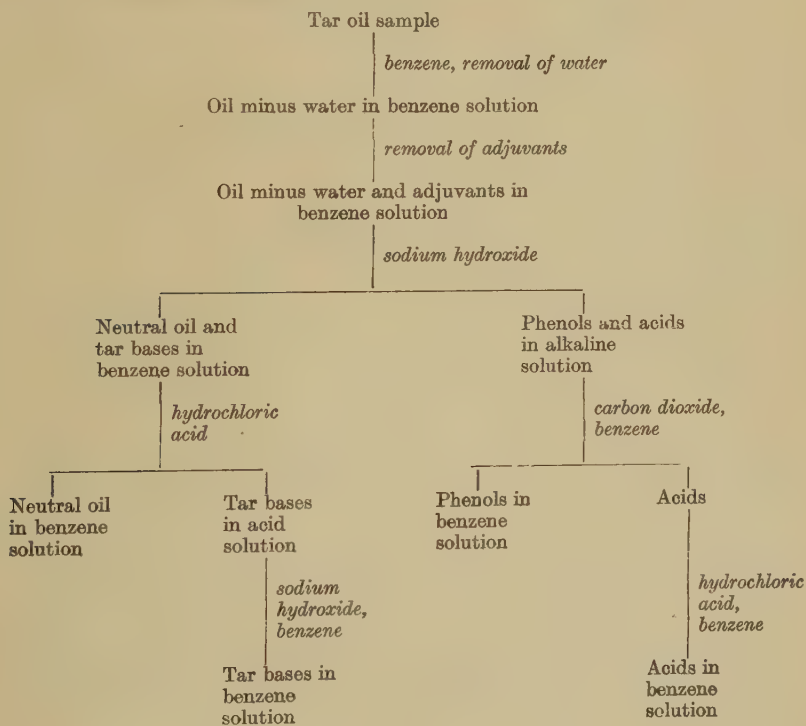
Ether is used as the solvent for the oil, and the tar acids and tar bases are successively removed by extraction with sodium hydroxide solution and aqueous hydrochloric acid. "Soaps" are separated from the alkaline solution of the tar acids by treatment with solid barium hydroxide. The neutral oil, tar acids and tar bases are recovered in ether solutions which are dried with anhydrous sodium sulphate, the solvent removed and the components weighed. No provision is made in the method for the determination of water content.

When used for the fractionation and analysis of the tar oil fungicides the method was found to have serious disadvantages. Large quantities of ether were required, the drying of the ether solutions was not entirely satisfactory and the solvent was held tenaciously by the tar constituents. Considerable amounts of material separated in the precipitation of the "soaps" and several additions of barium hydroxide were necessary. The filtration of the separated solids was troublesome, and even after much washing they appeared to retain

phenols. At many stages emulsions were formed and at times only partial separations were achieved. The difficulties found with the method seemed to arise chiefly from the use of ether as solvent and from omitting to remove adjuvants before proceeding to the separation of the main tar constituents.



(b) *Alternative method of analysis.*



The new procedure removes the water and formulating materials at an early stage in the analysis and also differentiates between phenols and other acids originating in the tar or derived from adjuvants. (The steps used in the method are as on previous page).

Tests with various solvents showed chloroform and benzene to be the most suitable; there was, however, evidence of interaction between chloroform and the alkaline solution of phenols and benzene has therefore been preferred.

The amount of material taken for analysis is adjusted to give approximately 25 g. calculated on a water-free basis. The water is removed by distillation with benzene using the Dean and Stark apparatus; excessive frothing may be overcome by inserting a condenser, through the jacket of which steam is passed, between the flask and the receiver. During this process adjuvants such as emulsifiers and emulsion stabilizers are precipitated in the oil solution, and these are then removed.

Considerable difficulty was met in effecting the separation of the oil and solids, but this was achieved satisfactorily by continuous extraction of the oil from the flask containing the mixture, using a new extraction assembly designed for the purpose (2). The flask containing the oil and solids is attached to a liquid extractor tube by a ground-glass cone inserted in the tube just below its side-arm. A glass disc with holes, fused to the lower edge of the cone, supports a filter-pad of cotton wool. The extended stem of a filter-funnel passes through the central hole of the disc. The oil in the mixture is washed over into a second flask by condensed benzene falling into the funnel and the extraction is continued until the benzene filtering through the pad is completely colourless. After the recovery of the oil, the solids remaining in the flask or held in the filter may be freed from benzene and weighed.

The separations of acids and bases from the oil solution are then carried out by counter-current extractions, in separating funnels, using benzene and 5 per cent. (by weight) solutions of sodium hydroxide and hydrochloric acid. Eight alkaline and five acid extractions are made. Phenols are separated from the alkaline solution by passing carbon dioxide before recovering the other acids. In all extractions using the separating funnel, agitation by inverting the funnel fifty times has been preferred to shaking. Water is conveniently removed from the benzene solutions of the phenols, other acids and bases by the Dean and Stark technique. The tar components are obtained by distillation from a water-bath of most of the benzene, the remainder of which is eliminated by azeotropic distillation with methyl alcohol followed by drying in an oven at 100°C. for a short period.

Three commercial fungicides (designated A, B and C) sent from Malaya and analysed earlier by the standard method for tar oil winter washes (1, p. 111) were re-examined by the new procedure. The results are given in Table I.

The outstanding differences lie in the values obtained for the neutral tar oil, which are appreciably lower when determined by the new method.

Seven more proprietary fungicides, also sent from Malaya, were analysed by the new procedure. The results are given in Table II.

The products differ markedly in their contents of neutral oil and phenols and contain low proportions of bases.

TABLE I.
ANALYSIS OF TAR OIL FUNGICIDES (PER CENT. BY WEIGHT)
BY THE OLD AND NEW PROCEDURES.

Material	Water	Solids	Neutral oil	Total acids	Phenols	Other acids	Bases
<i>Standard method for winter washes.</i>							
A	*	*	66.6	9.3	*	*	2.1
B	*	*	64.2	18.2	*	*	2.3
C	*	*	25.5	22.4	*	*	1.0
<i>New procedure.</i>							
A	6.6	17.2	57.0	—	11.0	1.4	2.3
B	6.7	12.5	55.3	—	18.3	0.8	2.1
C	49.5	2.4	14.9	—	28.9	1.1	0.8

*Not determined in the method.

TABLE II.
ANALYSIS OF TAR OIL FUNGICIDES (PER CENT. BY WEIGHT)
BY THE NEW PROCEDURE.

Material	Water	Solids	Neutral oil	Phenols	Other acids	Bases
G	46.5	6.2	10.9	34.3	1.6	2.0
H	7.6	7.6	38.6	31.3	1.4	1.3
I	50.0	2.4	19.4	28.0	2.0	0.7
J	54.5	3.7	14.7	23.7	0.5	0.3
K	49.9	5.9	21.9	22.9	0.9	2.1
L	56.2	3.1	6.7	19.4	0.3	0.7
M	4.8	21.7	67.8	8.2	1.0	4.8

Biological Tests.

(a) *Fungus inhibition by the components of proprietary fungicides.*

The laboratory method of bio-assay has already been described (1, p. 109). An account of the statistical arrangement and treatment of the tests has been given by Clarke (4).

Materials A and C and the fractions separated from them by the new procedure were tested in the laboratory against *C. fimbriata*; the results are given in Table III.

As already reported (1, p. 110, Table I) material C is appreciably more active against the fungus than material A, the inhibition levels, when related to the concentrations of the formulated products, being of a comparable order

TABLE III.

PERCENTAGE INHIBITION (2-4 DAY PERIOD) OF MYCELIAL GROWTH OF *C. fimbriata*
BY FRACTIONS OF PROPRIETARY COAL TAR FUNGICIDES.

	P.p.m.	Material A. Tested 24/8/54	Material C. Tested 29/6/54
Original (water-free basis)	200	23.5	74.5
	100	19.0	50.5
	50	8.5	28.0
Neutral oil	200	30.0	36.5
	100	17.0	18.5
	50	0.0	10.0
Phenols	200	100.0	73.0
	100	44.5	49.5
	50	10.5	31.0
Other acids	200	30.0	81.5
	100	13.0	49.5
	50	0.0	29.5
Bases	200	61.5	22.5
	100	36.0	18.5
	50	23.5	5.5
Solids*	200	7.0	0.0

Significant Differences :- P = 0.05 12.5 8.5
P = 0.01 16.5 11.0
P = 0.001 22.0 14.5

* Solids were not tested in the statistically designed experiment, but the plates were included in the incubator at the same time. Significant differences quoted, therefore, do not apply.

with those obtained earlier. The most important fungicidal constituents of both A and C are the phenols; the only other groups to show an appreciable effect are the bases separated from A and the "other acids" isolated from C. The neutral oils show a low activity.

(b) Tests for synergism.

Experiments were carried out to determine whether there was any synergistic effect between the constituents occurring in the proprietary products in the greatest proportions, namely the neutral oil and phenols. The fractions isolated (in June 1954) from material C by the new method were tested (in March 1955) alone and as mixtures. The results are given in Table IV.

TABLE IV.

PERCENTAGE INHIBITION (2-4 DAY PERIOD) OF MYCELIAL GROWTH OF *C. fimbriata*
BY PHENOLS AND NEUTRAL OIL ALONE AND IN ADMIXTURE.

	Phenols %	Neutral oil %	Mean growth mm.	Inhibition %
At 104 p.p.m. ..	100	0	2.63	74.7
	80	20	4.00	61.4
	60	40	4.25	59.1
	40	60	4.88	53.0
	20	80	6.38	38.5
	0	100	6.38*	38.5
At 55 p.p.m. . .	100	0	5.00	51.8
	80	20	5.63	45.8
	60	40	6.50	37.3
	40	60	6.75	34.9
	20	80	7.00	32.5
	0	100	7.13	31.3
Control	—	—	10.38	—

Significant Differences :—P = 0.05 1.46 14.1
P = 0.01 1.95 18.8
P = 0.001 2.58 24.9

*One plate lost.

The results at both levels of concentration show a steady falling off in inhibition from the values obtained with the more toxic phenols to those given by the neutral oil, and give no indication of a synergistic effect. A second experiment, using the tar acids D and neutral oil F sent to Malaya for field test (1, p. 113), also failed to show an interaction between these components.

(c) *Fungus inhibition by proprietary materials.*

The proprietary fungicides G–M whose analyses are given in Table II were also tested against the fungus, both in their original miscible oil or emulsion forms and also on a water-free basis. *p*-Phenyl phenol, at 25 p.p.m., was included in some of the tests as a standard fungicide. The results are given in Table V.

Judged from the tests on the formulated products at 400 and 200 p.p.m., the materials show a decline in toxicity from G to M. Further examination of the results shows that the products may be separated into two groups, one consisting of G, H, I and J and the other of K, L and M. Comparable concentrations of products within each group do not differ significantly from each other in toxicity (at $P = 0.05$), while those of the first group are significantly more active than those of the second (at $P = 0.05$).

TABLE V.

PERCENTAGE INHIBITION (2-4 DAY PERIOD) OF MYCELIAL GROWTH OF *C. fimbriata*
BY PROPRIETARY COAL TAR FUNGICIDES.

Material	As formulated			Water-free basis		
	P.p.m.	Tested 4/1/54	Tested 2/2/54	P.p.m.	Tested 29/3/54	Tested 10/4/54
G	400	100	—	200	84.0	—
	200	65.5	56.5	100	60.5	—
	100	—	34.5	50	39.5	—
H	400	—	91.0	—	—	—
	200	52.5	52.0	—	—	—
	100	14.5	—	—	—	—
I	400	85.5	—	200	—	81.5
	200	54.5	62.5	100	—	60.5
	100	—	37.5	50	—	34.0
J	400	85.5	—	200	74.5	—
	200	51.0	53.5	100	57.0	—
	100	—	33.0	50	44.5	—
K	400	60.0	—	200	66.5	—
	200	43.5	28.5	100	57.0	—
	100	—	24.0	50	38.0	—
L	400	69.0	—	200	—	69.0
	200	42.0	42.0	100	—	55.0
	100	—	15.0	50	—	24.0
M	400	52.5	—	200	—	26.5
	200	31.0	45.0	100	—	17.0
	100	—	28.5	50	—	4.0
<i>p</i> -Phenyl phenol	25	38.0	45.0	—	—	—

Significant	P = 0.05	..	11.5	7.5	9.0	7.0
Differences :—	P = 0.01	..	13.5	10.0	12.0	9.5
	P = 0.001	..	20.0	13.0	15.5	12.5

An analysis of the results was made to determine to what extent the fungicidal activities of the products could be ascribed to particular constituents determined by the new method. At the level of 400 p.p.m. the partial correlation coefficient of the percentage inhibition with the percentage phenols content (eliminating the variation within the range of materials in the percentage of

neutral oil) was 0.866, significant at $P = 0.01$. At the same level of concentration, the partial correlation coefficient of the inhibition due to the neutral oil, eliminating the effect of the phenols, was 0.086, certainly not significant. At the 200 p.p.m. level, the corresponding coefficients were 0.811 and 0.127, the former being significant at $P = 0.05$ (and almost significant at $P = 0.01$). At 100 p.p.m., neither coefficient was significantly different from zero.

The results show that, judged at the higher levels of concentration of the formulated products, the phenols contents alone give a measure of their fungicidal activities as determined by the laboratory method of bioassay.

Discussion.

The alternative method of analysis proposed represents, in our view, a step forward in the chemical examination of tar oil fungicides. Not only does it give a measure of the contents of water and formulating solids, but the early removal of these ensures a more satisfactory separation of the acids, bases and neutral oil. Difficulty, however, was still met in the analysis of some of the proprietary products. The tests on G, I, J and K went smoothly and total recoveries within the range of 95.5 to 102.7 per cent. were obtained; with H and L solids continued to be thrown out after the initial separation procedure, probably due to the incomplete removal of water. The high recovery value (108 per cent.) obtained with M was attributed to the retention of solvent by the tar components. The method, however, is promising and with further experience may provide the basis of a standard test for materials of this kind.

The phenols clearly play a predominant part in determining the efficiency of the proprietary products. Both the determination of phenols and the laboratory bioassay have placed the fungicides in an order of efficiency which has followed closely the order observed from tests with earlier consignments on the control of the disease in the field. The phenols contents, however, although of value in assessing the potential effect, do not give more than an approximate measure of toxicity since the particular phenols used may influence the level of control obtained. The products I and J, for example, differ in their phenols contents but show the same order of inhibition in the laboratory tests, probably due to the use of the more toxic phenols in the formulation of J. The results from this and earlier work suggest that a minimum content in the formulated product of about 25 per cent. of the more active phenols (boiling point 220°C . and above) is necessary to achieve a reasonable degree of efficiency under the normal conditions of application in the field.

The possibility of a synergistic effect between the tar components has been considered but no evidence of an interaction between the chief constituents, the phenols and neutral oil, has been detected. The tar bases show some activity, but occur in insufficient quantities in the fungicides to contribute materially to their overall toxicities. The bases may, however, influence the activity of the other components, but this has not been examined.

A feature of the laboratory bioassay has been the reproducibility of the levels of inhibition of the fungus obtained in comparable tests over an appreciable period. *p*-Phenyl phenol was included in some of the experiments as a standard fungicide; more recently we have preferred to use *o*-phenyl phenol which at concentrations of 75, 15 and 3 p.p.m. has consistently given

percentage inhibitions of the order of 80, 45 and 20 respectively. Work in progress on the fungicidal activities of individual phenolic, neutral and basic tar components will be reported later.

Summary.

- (1) A method of analysis of tar oil fungicides is described. Phenols, bases and neutral oil are determined after the separation of water and formulating solids.
- (2) The fungicidal efficiencies against *Ceratostomella fimbriata* of proprietary tar oil fungicides and of constituent fractions have been assessed by a laboratory method of bioassay.
- (3) The results of bioassay have been correlated with those of chemical analysis. The predominating effect of the phenols in determining the efficiency of the fungicides has been confirmed. No evidence has been detected of a synergistic effect between the phenols and the neutral oil.

Acknowledgments.

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SPRAY APPLICATION PROBLEMS :

XIII. DETERMINATION OF CAPTAN DEPOSITS : PROGRESS REPORT.

By J. T. MARTIN and J. A. PICKARD.

Introduction.

One of the most promising of the new organic fungicides is N-trichloromethylmercapto-4-cyclohexene-1,2-dicarboximide, for which the common name captan has been agreed by British and North American authorities. Preparations containing the chemical have been known for some time as SR 406 or Orthocide. Captan is one of a new group of fungicidal chemicals described by Kittleston (1).

Particular interest has been shown in the use of captan against apple and pear scab. East Malling Research Station has reported (2) that the most satisfactory results so far recorded from new materials were given by captan and glyoxalidine. Captan has been included in trials on scab control at Long Ashton for the past five years and its early promise has been maintained (3, 4, 5). Captan at 0.1% has given a significantly better control of scab on Cox fruits than lime sulphur, with a larger crop. No instances of damage have been recorded in Britain, and it is likely to prove suitable as a post-blossom spray on sulphur-sensitive varieties of apples and pears. In recent trials, however, there has been evidence that captan has little or no effect on apple mildew caused by *Podosphaera leucotricha* (6). In consultation with East Malling Research Station, work has also been carried out at Long Ashton on the value of captan in reducing *Botrytis* mould on strawberries (7, 8, 9).

Captan reacts with alkalis, and so should not be used with alkaline sprays such as Bordeaux mixture or high concentrations of lime sulphur. Its toxicity to man is low, but powders containing it may irritate the throat and eyes.

An analytical method has recently been described by Kittleston (10) for the determination of captan deposits on tomatoes. As part of a programme of work on spray deposits, this method has been examined and has been used with modifications to determine captan residues on strawberries, apples and pears.

The Method of Analysis.

Kittleston's method is based upon the development of a yellow colour when captan, removed from the fruits by washing with chloroform, is heated with resorcinol. The colour, in alcoholic solution, is measured spectrophotometrically.

No provision was made in the original method for the removal of possible interference by other materials extracted by the chloroform. We have not so far examined tomatoes but, with other fruits, wax and pigment were troublesome. The pigment gave unduly high "blank" readings in the analysis of untreated fruits, and wax, precipitated by the alcohol, caused the scatter of light in the colour assessment. Columns of absorbents such as activated charcoal, fuller's earth and some preparations of silica gel were unsatisfactory

for removing these sources of interference ; finally activated alumina was used, in sufficient quantity just to retain the pigment and most of the wax. The use of alumina in amounts greater than this led to loss of captan.

We have also found that in neutral ethyl alcohol (dried over calcium oxide and distilled) the colour was unstable. When alcohol containing a small amount of alkali was used, both the initial intensity of the colour and the rate of falling-off were increased. The incorporation with the alcohol of small and varying amounts of sulphuric acid gave a colour of lower optical density than that obtained with neutral or alkaline alcohol, but the colour was stable for long periods. Its intensity, within the limits tested, was also independent of the amount of acid used. We have therefore preferred to measure the colour in acid-alcohol solution. Absorption curves over the range 3,500–6,300 Å were determined using the Unicam S.P. 600 spectrophotometer ; maximum absorption occurred at 4,250 Å as reported by Kittleson. The absorption curves for captan in neutral and acid alcohol solutions are shown in Fig. 1.

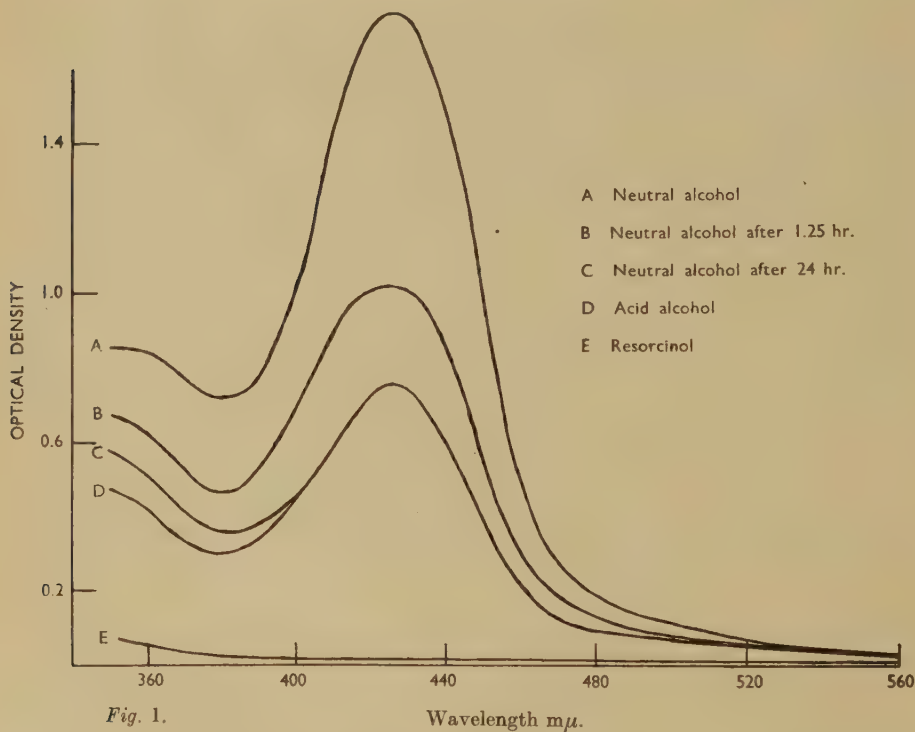


Fig. 1.

Some samples of resorcinol (analytical reagent grade) were found to be unsuitable, but the difficulty was overcome on purification by sublimation *in vacuo*. The use of 1 g. of resorcinol as recommended by Kittleson led to the separation of crystals above the solution in the optical cell. 0.3 g. of resorcinol was found to be the optimum quantity for proper admixture with the extract, although 0.1 g. was sufficient for the development of the colour.

The method of analysis used was as follows :—

Reagents.

- Chloroform : Analytical reagent (A.R.) grade redistilled before use.
 Resorcinol : Analytical reagent (A.R.) grade, sublimed.
 Alumina : Activated, for chromatographic analysis (Spence Type H).
 Acid-alcohol : Ethyl alcohol (redistilled) containing 10 per cent. by volume of 0.1 N aqueous sulphuric acid.

Extraction of fruits.

100 g. of strawberries were washed with 50 ml. and then four successive portions of 25 ml. of warm chloroform, with decantation through a cotton wool filter. The extract was concentrated by gentle distillation, made up to 50 ml. volume, and suitable aliquots were taken to give readings in the range 200–400 μ g. captan. Individual apples and pears were washed with a jet of warm chloroform, successive washings being taken to ensure complete recovery.

Analytical procedure.

When the aliquot taken for analysis exceeded 10 ml., it was reduced to approximately this volume by passing a stream of dry air over its surface at 45–55°C. The solution was then passed through 0.5 g. of alumina (supported on cotton wool in a glass tube 5–6 mm. diam.) and washed through with four successive portions of 2 ml. of chloroform. To the percolate (in a boiling tube) 0.3 g. of resorcinol was added, and the solvent was removed to dryness with a stream of air at 45–55°C. The tube was kept in an oil bath at 135°C. for fifteen minutes, with occasional rotation. After removal from the bath, and before solidification occurred, 10 ml. of acid-alcohol were added, the tube was glass-stoppered and allowed to stand for 1 hour. Any opalescence due to wax was removed by filtration and the optical density was determined using a Hilger Spekker Photoelectric Absorptiometer with a 1 cm. cell and violet filter No. 601.

A standard curve was prepared using captan recrystallized from absolute alcohol (m.p. 174.5°C.; N found 4.51, 4.43%; theoretical 4.66%). This is shown in Fig. 2. All-glass apparatus was used throughout the work.

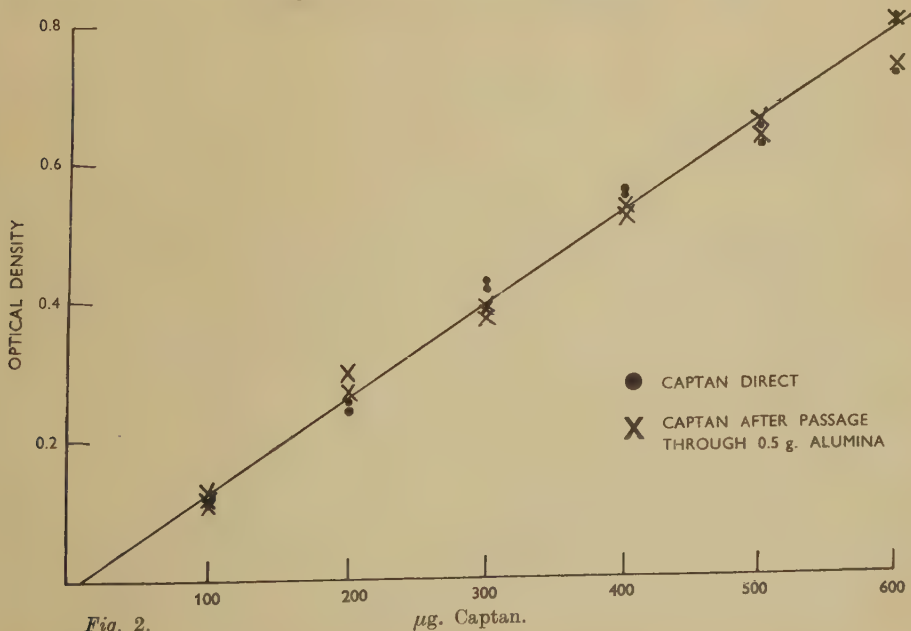


Fig. 2.

Recovery of captan by the method.

(a) *From an extract of unsprayed fruits.* Unsprayed strawberries were extracted with chloroform and the extract made up to volume (4 g. fruit/ml.). Determinations on 5 ml. aliquots gave values equivalent to 12 to 14 $\mu\text{g.}$ of "captan." Increasing amounts of captan, from 100 to 500 $\mu\text{g.}$, were added to further 5 ml. aliquots, and the determinations repeated. The results are shown in Table I.

(b) *From an extract of sprayed fruits.* Fruits from strawberry plants sprayed with captan were washed with chloroform and the extract made up to volume (4 g. fruit/ml.). Determinations of captan, on 5 ml. aliquots of the extract, gave values of 283, 295, 302, 302 and 288 $\mu\text{g.}$, with an average content of 294 $\mu\text{g.}$

300 $\mu\text{g.}$ of captan, in chloroform, were added to further 5 ml. aliquots and the recoveries found (Table II).

TABLE I.

RECOVERY OF CAPTAN ADDED TO EXTRACT OF UNTREATED STRAWBERRIES.

Added $\mu\text{g.}$	Found $\mu\text{g.}$	Recovered $\mu\text{g.}$ after correction for average blank determination of 13 $\mu\text{g.}$
100	122	109
	112	99
200	223	210
	221	208
300	327	314
	320	307
400	425	412
	411	398
500	516	503
	521	508

TABLE II.

RECOVERY OF CAPTAN ADDED TO EXTRACT OF TREATED STRAWBERRIES.

Added $\mu\text{g.}$	Found $\mu\text{g.}$	Recovered $\mu\text{g.}$ after correction for average initial content of 294 $\mu\text{g.}$
300	614	320
300	608	314
300	593	299
300	609	315
300	595	301

The recoveries, in both tests, are satisfactory. The greatest discrepancy, 20 $\mu\text{g.}$, on the 20 g. of fruit represented by 5 ml. of extract, is equivalent to 1 p.p.m. captan.

Tests on Crops in the Field.

Strawberries.

In an investigation of the value of captan in controlling *Botrytis* on strawberry fruits, plants were sprayed by hand on the 17th May, 1st June and 29th June, 1954, with a dispersible powder formulation containing 50 per cent. of captan at the rates of 5 and $2\frac{1}{2}$ lb. per 100 gallons. Samples were taken on the 7th, 14th and 18th July, and the deposits on the fruits, separated from the calyces with a scalpel, were determined. The results are given in Table III.

TABLE III.
CAPTAN DEPOSITS ON STRAWBERRY FRUITS.

Sampling date	Average fruit weight g.	Spray applied			
		Captan 0.125%		Captan 0.25%	
		$\mu\text{g. per fruit}$	p.p.m.	$\mu\text{g. per fruit}$	p.p.m.
7 July ..	11	143	13	200	18
14 July ..	7	65	9	84	12
18 July ..	6.5	50	8	107	17
Unsprayed ..	—	<10	<1	<10	<1

Rainfall 17th May–18th July; 7.20".
7th July–18th July; 1.43".

The degree of persistence of captan is of interest since the rainfall was slightly above average for the time of year.

Immediately after picking, sprayed and untreated fruits were canned in syrup or water or made into jam for storage tests. Tests for captan residues in the canned fruits and jam were made four months later. On opening the cans, the juice was separated from the fruits, the fruits were macerated, and both fractions were extracted exhaustively with chloroform. Water was removed from the jam, the residue powdered and extracted with chloroform. No captan could be detected in any of the processed materials. This was not due to failure to extract since appreciable proportions (50 to 90 per cent.) of captan could be recovered when it was added at the rate of 300 $\mu\text{g.}$ to each 100 ml. of the juice or the macerate obtained from unsprayed fruits canned in syrup or water. It is likely that the captan was decomposed in processing.

Tests were also made on the 7th, 14th and 18th July on the foliage of sprayed and unsprayed plants, and on the calyces removed from the fruits. On the 7th July, deposits on the leaves were of the order of 150 p.p.m., on a fresh weight basis, after the three applications of captan at 0.125 per cent., and 500 p.p.m. after the three treatments at 0.25 per cent.; deposits on the

calyces reached 400 p.p.m. at the lower, and 800 p.p.m. at the higher concentration of captan. High levels of residues persisted until the 18th July. The high values, in p.p.m., reflect the large surface area of leafy tissues in relation to their weight, but the ease of wetting of foliage compared with that of fruits and the retention of excessive amounts of the spray by the calyx tissue may also have contributed to the deposits found.

Blank determinations on unsprayed foliage and calyces were of the order of 10 to 20 p.p.m. expressed as captan. Although these values are of little significance compared with those of the captan deposits, more work is needed on the elimination of interference in the method of analysis.

Apples and Pears.

Tests were made to determine the levels and persistence of captan deposits resulting from a single application made late in the season. Cox apple trees and Conference pear trees were sprayed to run-off on 28th August, 1954, with 0.1 per cent. captan formulated as dispersible powder with the incorporation of dioctyl sodium sulphosuccinate at 0.025 per cent. Individual fruits were examined at intervals up to early October, when the crops were harvested. The results are shown in Tables IV and V.

TABLE IV.
CAPTAN DEPOSITS ON APPLE FRUITS.

	Average fruit weight g.	μ g. captan per fruit		p.p.m. captan	
		mean	s.e. of mean	mean	s.e. of mean
30 August ..	52	64	18	1.2	0.5
6 September ..	58	64	9	1.1	0.1
13 September ..	54	59	8	1.1	0.2
20 September ..	64	21	4	0.3	0.1
27 September ..	74	31	6	0.4	0.1
<i>Unsprayed</i> ..	—	10	1	0.1	—

The results show a falling off in deposits when these are expressed as p.p.m. or as μ g. of captan present on the fruits. Some weathering of the captan had taken place, the amounts held on the fruits falling to about half of their original levels over the period of one month. The greater reductions in the values for deposits when these are expressed as p.p.m. result from the weathering of the captan allied with the increase in the weight of the fruits over the period of the test.

Work was also carried out on captan deposits on the apple and pear foliage. As with strawberry leaves, interference in the method could not be completely eliminated. Initial deposits on apple foliage, corrected for values on unsprayed leaves, were of the order of 100 p.p.m., on a fresh weight basis, falling to levels of about 40 p.p.m. at the end of the experiment. Deposits on

TABLE V.
CAPTAN DEPOSITS ON PEAR FRUITS.

	Average fruit weight g.	μ g. captan per fruit		p.p.m. captan	
		mean	s.e. of mean	mean	s.e. of mean
30 August ..	54	77	14	1.4	0.3
6 September ..	91	74	9	0.8	0.1
13 September ..	94	69	14	0.8	0.2
20 September ..	107	73	12	0.7	0.3
27 September ..	137	38	4	0.3	0.1
4 October ..	207	59	14	0.3	0.1
11 October ..	—	45	9	0.2	0.1
<i>Unsprayed</i> ..	—	11	1	0.1	—

Rainfall: 30 August–11 October; 7.22".

the pear foliage throughout the test were somewhat lower. The results, confirming those obtained with the fruits, showed that captan had persisted well during the first half of the experimental period, during which 3.5" of rain had fallen.

Summary.

Captan deposits on the fruits of strawberry, apple and pear have been determined. Three applications to strawberries of captan at 0.125 and 0.25 per cent. gave deposits of the order of 10 and 20 p.p.m. respectively. One application, late in the season, of captan at 0.1 per cent. to apples and pears gave deposits of approximately 1 p.p.m., falling to negligible values at harvest time. Captan persisted well under the rainfall conditions during the trials.

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SPRAY APPLICATION PROBLEMS :

XIV. LABORATORY AND FIELD EXPERIMENTS WITH BURGUNDY MIXTURES.

By E. SOMERS.

Introduction.

Burgundy mixture is prepared by the interaction of solutions of copper sulphate and sodium carbonate. Mond and Heberlein (1) considered that the reaction product was a mixture of a basic copper carbonate and basic copper sulphates, its composition varying with the ratio of copper sulphate to sodium carbonate. They found that neutrality was reached at the molar ratio, $\text{CuSO}_4:\text{Na}_2\text{CO}_3$, of 1.00:0.93 and recommended these proportions for the preparation of sprays. In earlier work Pickering (2) had recommended a 1.00:1.61 mixture, which gives the minimum amount of soluble copper. Butler (3) investigated the sedimentation and phytotoxicity of different Burgundy mixtures and concluded that mixtures with ratios ranging from 1.00:0.87 to 1.00:1.30 were safe to different types of foliage and that 1.00:0.87 was the most suitable ratio. The mixtures used in practice vary from 1.00:0.87 to 1.00:1.22 and are equivalent to 0.25 per cent. metallic copper.

The recommendations for Burgundy mixtures given above are founded on the physics and chemistry of the spray suspensions and on phytotoxicity tests, but there are no data on the fungitoxicities of different mixtures or of their tenacities on foliage. To obtain a better assessment of these properties a field experiment was designed to determine whether Burgundy mixtures, of constant copper but varying sodium carbonate concentrations (over the range recommended above), might prove variable both in residue level on potato foliage and in the protection afforded against potato blight (*Phytophthora infestans*). Bordeaux mixture was used as a standard treatment at the same copper concentration. The tenacities of these mixtures on an artificial surface, after a standard washing treatment, were determined in the laboratory.

Laboratory Experiments.

Materials. The Burgundy mixtures were prepared by adding molar copper sulphate solution to dilute sodium carbonate in the spray container ; similarly, for Bordeaux mixture, molar copper sulphate was added to a suspension of calcium hydroxide. All materials were of laboratory grade.

Five Burgundy mixtures were used, ranging from 10:10:100 to 10:40:100, where the ratio is expressed as $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (lb.) : $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ (lb.) : water (gal.).

As all the Burgundy suspensions were sprayed within one hour of preparation no consideration was given to the change to malachite they undergo on standing for longer periods, for it is not known whether the ageing reactions of the spray suspensions are paralleled by similar changes in the dried and weathered spray deposit.

Tenacity of spray deposits. Using the technique and apparatus previously described (4), Burgundy and Bordeaux mixtures were sprayed on to 7.6×2.5 cm. microscope slides which had been coated with cellulose acetate. The spray

apparatus gave uniform deposits of $10 \mu\text{g. Cu/cm}^2$ on each slide, with a coefficient of variation between the deposits $< 5\%$. The slides, after drying for 24 hr. at 25° , were washed by a horizontal jet of water ("rainfall" of 0.42 cm./10 sec.) in a standard wash apparatus for 10 and 60 sec. The deposits were removed from the slides with hot 1:1 nitric acid and copper was determined colorimetrically with sodium diethyldithiocarbamate in 0.1% gelatine (5).

The tenacities of the spray deposits given in Table I are defined as the ratio of the weight of copper in the washed deposit to the copper content of the initial deposit; they are the mean values of three determinations whose values differed by $< 8\%$. The pH values of the Burgundy mixtures were determined within 5 min. of preparation. Table I shows that only the 10:10:100 and 10:40:100 Burgundy mixtures had tenacities appreciably lower than that of the Bordeaux mixture.

TABLE I.
TENACITY OF BURGUNDY AND BORDEAUX MIXTURE
SPRAY DEPOSITS ON CELLULOSE ACETATE.

Spray material		Molar ratio CuSO_4 : Na_2CO_3	pH	Tenacity ($\times 100$)	
				after 10 sec. wash	after 60 sec. wash
10:10:100	Burgundy	1.00:0.87	5.61	47	20
10:11.4:100	"	1.00:1.00	5.78	98	74
10:14:100	"	1.00:1.22	6.31	100	92
10:18.45:100	"	1.00:1.61	8.14	87	87
10:40:100	"	1.00:3.50	9.59	29	26
10:12.5:100	Bordeaux	—	—	100	88

Field Trial.

In 1954 a field trial was carried out to compare the fungicidal efficiencies of the different Burgundy mixtures with the standard Bordeaux mixture for the control of *Phytophthora infestans* on potato foliage. The spray treatments used were as given in Table I.

The experimental plot was at the end of a block of King Edward potatoes, 90×10 yd. The plot consisted of fifteen rows, three yards long, and it was divided into eight randomized blocks, each containing six individual plots of three or four potato plants. To each of these individual plots one of the six treatments was applied. Guard plants were left between treated plots in the same row to obviate errors caused by spray drift. A block ten yards long, which separated the trial plot from the rest of the field of potatoes, was used as the unsprayed control.

The mixtures were sprayed (3rd August) with a hand-pump of the "Solo" type to give complete wetting of the foliage.

Sampling and analysis of spray deposit. 25 leaflets were collected at random from each plot, avoiding new growth at the top, and old leaves at the

bottom, of the plants. 1.60 cm. discs were cut, with a stainless steel cork borer, from the centre of bundles of these leaflets. The samples were ashed, dissolved in nitric acid, and copper was determined as above. A copper blank of unsprayed leaves was determined on each sampling date.

Blight assessment. The incidence of potato blight was estimated with the British Mycological Society assessment key (6).

Results.

Initial deposits. The initial deposits of copper from the different treatments are given in Table II, together with the differences necessary for significance. The 10:10:100, 10:11.4:100, and 10:14:100 Burgundy mixtures gave initial deposits which did not differ significantly but which were significantly greater than those of the 10:40:100 Burgundy and the Bordeaux mixture. The 10:18.45:100 Burgundy mixture occupied an intermediate position between the two groups.

Tenacity of the deposits. The tenacities in Table II were transformed to "angles of equal information" and analysed statistically. At the first sampling there were no significant differences, at the 5% level, between the tenacities of any spray treatment. There were, however, some obvious differences at the second sampling, on 25th August. The tenacity of the 10:10:100 Burgundy deposits was significantly greater (at the 5% level) than the tenacities of all the other treatment deposits with the exception of 10:14:100 Burgundy. All the other treatment tenacities were significantly higher (at the 1% level) than that of the 10:40:100 Burgundy although they did not differ between each other.

Leaf scorching. Some of the Burgundy mixtures damaged the potato foliage: brown and red spots appeared on the leaves, which in some cases withered and died. Three days after spray application, up to 10% of the leaf area treated with 10:40:100 Burgundy had been destroyed, 10:10:100 Burgundy had affected about 1% of the leaf area whilst the 10:18.45:100 mixture caused slight scorching estimated at 0.5%. There was no damage with any of the other treatments.

Control of blight. Table III gives the estimated percentage areas of foliage destroyed by blight on the treated plots. The 10:40:100 Burgundy gave poorer blight control (at 5% level), at all times, than any of the other treatments. There were no significant differences in control (5% level) between any of these other treatments except on the final sampling date, 20th September. On this date 10:10:100, 10:11.4:100, and 10:18.45:100 Burgundy mixtures gave less effective blight control (significant at 5% level) than did 10:14:100 Burgundy and the Bordeaux mixture. There was no significant difference (5% level) between these last two treatments.

Fig. 1 shows the control of blight achieved by the most and least effective Burgundy mixtures, i.e. 10:14:100 and 10:40:100, and by Bordeaux mixture, compared with the blight incidence on the unsprayed guard block. The rest of the potato plants in the field, a block 77 × 10 yd., were sprayed on 5th August with a commercial basic copper carbonate preparation and succinate wetter, at the rate of 0.06% Cu, and the blight progress on this block is also shown in Fig. 1. As the blight on the guard block and on the rest of the field was estimated on single plots the results cannot be strictly compared with those of the experimental trial; however, the order of significant difference

TABLE II.
BURGUNDY AND BORDEAUX RESIDUES AND TENACITIES ON POTATO FOLIAGE, 1954.

Spray Treatment	Date of Sampling				
	3rd August	9th August		25th August	
	Initial deposit (mg. Cu/100 cm. ² leaf)	Residue (mg. Cu/100 cm. ² leaf)	Tenacity (× 100)	Residue (mg. Cu/100 cm. ² leaf)	Tenacity (× 100)
Burgundy					
10:10:100	3.02	3.36 ± 0.33*	111	2.13 ± 0.39	70
10:11.4:100	3.65	3.25 ± 0.45	89	2.21 ± 0.32	60
10:14:100	3.22	3.02 ± 0.40	94	2.03 ± 0.31	63
10:18.45:100	2.86	2.93 ± 0.49	103	1.54 ± 0.34	54
10:40:100	2.14	1.94 ± 0.24	90	0.73 ± 0.21	34
Bordeaux— 10:12.5:100	2.23	2.11 ± 0.31	94	1.25 ± 0.17	56
	Minimum sig. diff. at :— P = 0.05 0.64 P = 0.01 0.87 P = 0.001 1.14	Rainfall (in.) 3rd–9th August (0.52, 0.15, 0.21, 0.47) = 1.35		Rainfall (in.) 9th–25th August (0.11, 0.03, 0.24, 0.30, 0.01, 0.10, 0.36, 0.21, 0.02, 0.07) = 1.45	

*The limits of the residue means given above are approximate 95% confidence limits, i.e. ± 2 S.E.

obtained in this trial shows that the Burgundy mixtures at 0.25% Cu gave a real improvement in the control of blight compared with the commercial preparation at 0.06% Cu.

TABLE III.

THE PERCENTAGE AREA OF SPRAYED POTATO FOLIAGE DESTROYED BY BLIGHT.

Spray Treatment	Date of Sampling					
	26th Aug.	30th Aug.	2nd Sept.	7th Sept.	13th Sept.	20th Sept.
Burgundy—						
10:10:100	40 ± 10*	50 ± 10	60 ± 10	80 ± 10	90 ± 5	98 ± 2
10:11:4:100	50 ± 10	60 ± 10	70 ± 10	80 ± 10	90 ± 5	98 ± 4
10:14:100	35 ± 10	50 ± 10	60 ± 10	70 ± 10	80 ± 10	95 ± 5
10:18:45:100	50 ± 10	50 ± 10	60 ± 10	80 ± 5	85 ± 10	97 ± 3
10:40:100	60 ± 10	70 ± 5	75 ± 5	95 ± 2	97 ± 1	99.5 ± 0.5
Bordeaux—						
10:12:5:100	35 ± 10	50 ± 10	60 ± 10	70 ± 10	80 ± 10	90 ± 2

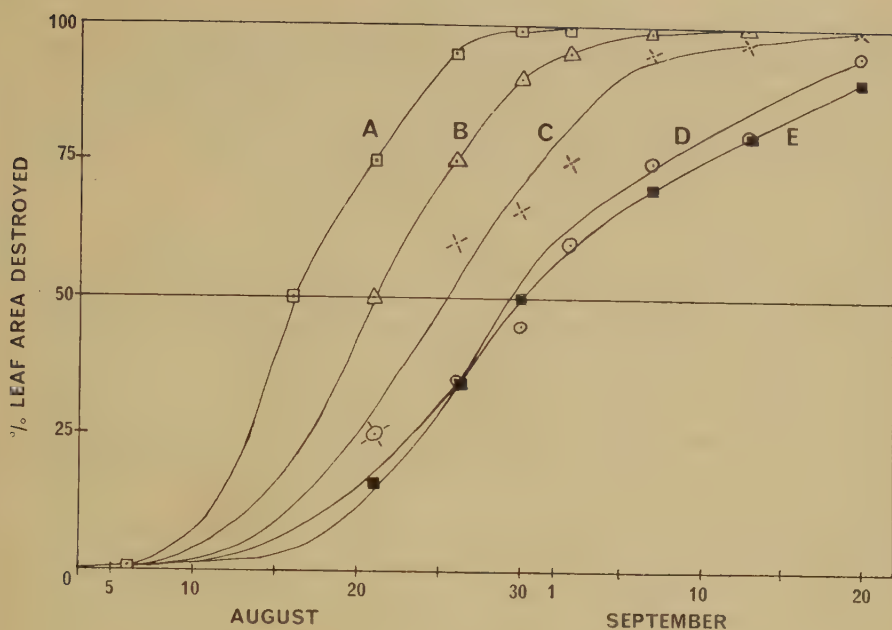
*Approximate 95% confidence limits of means.

Discussion.

The supposed inferiority of Burgundy mixture to Bordeaux as a fungicide is based on its poorer tenacity and its tendency to scorch foliage, whilst the advantages of Burgundy are that it is a more predictable material to prepare and is free from gritty residues that are likely to abrade spray nozzles and machinery. The results above, on potato foliage, show that over a certain range of Burgundy mixtures its disadvantages can be eliminated.

Scorching of potato foliage can best be avoided by preparing mixtures in the range 10:11:4:100–10:18:45:100, i.e. pH 5.8–8.1. The highest initial deposits and tenacities in this range were obtained with the 10:11:4:100 and 10:14:100 mixtures, which gave copper deposits almost twice as great as those given by the Bordeaux mixture. However, in the control of potato blight the smaller deposits of Bordeaux were more effective than the deposits of the 10:11:4:100 mixture and equally as effective as those of 10:14:100 Burgundy. The laboratory-determined tenacities of the spray mixtures on cellulose acetate agreed quite well with their tenacities on potato leaves, except for the low value given by 10:10:100 Burgundy in the laboratory tests. On cellulose acetate, as on potato, the tenacity of Bordeaux can be at least equalled by Burgundy mixtures in the range 10:11:4:100–10:18:45:100.

From the above work it appears that the most suitable Burgundy is the 10:14:100 mixture prepared by adding concentrated copper sulphate solution to dilute sodium carbonate. The molar ratio of this mixture, 1.00:1.22, is greater than the ratios recommended by Mond and Heberlein (1), and Butler (3), but less than that of Pickering's mixture (2).



- A $\square$ = Unsprayed.
 B $\triangle$ = Basic copper carbonate, with wetter.
 C $\times$ = 10:40:100 Burgundy mixture.
 D $\odot$ = 10:14:100 Burgundy mixture
 E $\blacksquare$ = 10:12:5:100 Bordeaux mixture

Fig. 1. Potato blight progress curves, 1954.

Summary.

- (1) A field trial of the tenacity and fungicidal effectiveness (as measured by resistance to potato blight) of different Burgundy mixtures has been carried out, with Bordeaux as a standard treatment.
- (2) The tenacities of these mixtures on cellulose acetate have been determined in a laboratory wash apparatus.
- (3) 10:14:100 Burgundy appears to be the most suitable mixture for application to potato foliage. It is as efficient a fungicide as Bordeaux mixture of equivalent copper concentration and is without the disadvantages entailed in preparing and applying the latter.

Acknowledgments.

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SPRAY APPLICATION PROBLEMS :

XV. COPPER AND DDT DEPOSITS FROM LARGE AND SMALL VOLUME APPLICATION.

By N. G. MORGAN and J. T. MARTIN.

Introduction.

Considerable attention has recently been given to achieving efficient pest and disease control at a lower cost of time, labour and materials. The introduction of automatic spraying machines, using large volumes of wash, has appreciably reduced the labour requirement and spraying time : small volume air-flow spraying now promises a saving not only of time and labour but also of materials (1).

The successful development of a new method of spray application requires a critical examination of its field performance. Measurement of the degree of pest or disease control is important, but this gives insufficient data on which to base improvements unless it is related to the amount and distribution of spray material on the target and to the conditions under which the application is made. The collection of deposits on glass plates or filter papers and the addition of dyes to the spray fluid provide useful indications of spray distribution. Because of the differences in the surfaces, however, these methods do not necessarily give a true picture of the deposit on the crop : this can be obtained only by an examination of the treated plant. This report gives the results of trials using copper on potato foliage and DDT on apple trees.

COPPER DEPOSITS ON POTATO FOLIAGE.

Materials and Methods.

The spray materials used were Burgundy mixtures (x:x:100) of different copper concentrations containing dioctyl sodium sulphosuccinate (0.025 per cent.) wetting agent, and a proprietary basic carbonate. They were applied, in August 1953, to Dunbar Standard potatoes :—

- (a) by a row-crop hydraulic sprayer at the rate of 98 gal. per acre ;
- (b) by a row-crop hydraulic sprayer at the rate of 45 gal. per acre ;
- (c) by an experimental air-flow mist sprayer at the rate of 40 gal. per acre.

The hydraulic sprayer used was a tractor drawn and driven trailer machine with a 100 gal. tank and a $\frac{3}{4}$ " B.S.P. gear pump delivering wash to a rear-mounted 20 ft. boom fitted with 28 spray nozzles ($\frac{1}{4}$ " B.S.P.) 9" apart (2). Discs of $\frac{4}{64}$ " diameter aperture were used for large volume spraying and of $\frac{2\frac{1}{2}}{64}$ " aperture for small volume spraying. The spray patterns from the nozzles, directed vertically downwards, were contiguous at a height of 12" above the crop and covered 8 rows of potatoes planted 2' 6" apart. Flow pressure was adjusted to 75 lb. per sq. in. ; the tractor speed was $2\frac{1}{2}$ m.p.h.

The air-flow mist sprayer consisted of a tractor mounted and powered centrifugal paddle fan delivering 2,000 cu. ft. of air per minute at 4" water gauge pressure through a 10" diameter outlet at right angles to the direction of travel. A gear pump delivered the spray liquid from forward-mounted tanks to a circular feed pipe at the fan outlet at a flow pressure of 75 lb. per sq. in. Six $\frac{1}{4}$ " B.S.P. spray nozzles with discs of $\frac{2\frac{1}{2}}{64}$ " aperture, fitted to the feed

pipe, discharged the spray liquid into the air-stream at an angle of 25° (Plate VII). Five rows of potatoes were sprayed horizontally across the rows with and against the wind.

Sampling and Analysis.

At the time of the trials, the terminal portions of the haulms were erect and the remainder prostrate. Pairs of leaflets were taken at random, soon after the spray had dried, from the top and middle of the haulms of five plants in each treated block. One leaflet from each pair was used for the determination of copper by sodium diethyl dithiocarbamate using the standard method and colour disc prepared by Tintometer Ltd., and the other for the assessment of the distribution of the deposit by the plaster technique (3). The results of the analyses, each representing the mean deposit on up to 50 leaves, are given in Table I and plaques showing the distribution of the deposits are shown in Plate VII.

TABLE I.
COPPER DEPOSITS ON POTATO LEAVES.

Treatment	Material	Cu per cent.	Volume	Mean deposit $\mu\text{g. Cu/sq. cm.}$	
				Top	Middle
1	Burgundy	0.10	} large, run-off	4.4	5.1
2	"	0.25		12.4	11.2
3	"	0.10	} small	2.9	2.1
4	"	0.25		6.4	3.4
5	"	0.50		5.1	7.8
6	"	1.25		11.5	8.2
7	"	1.25	small, air-flow	19.1	10.9
8	Carbonate	0.10	} large, run-off	3.7	2.6
9	"	0.25		7.1	4.2

Tests were made to determine the proportion of spray material retained by the foliage. Paper sheets were placed beneath the haulms and on open ground and Burgundy mixture (1.25 per cent. Cu) was discharged over the targets at large and small volume rates with the nozzles set 4' from the ground. Judged from the amounts of copper, determined chemically, that were deposited on the sheets in the open and beneath the haulms, 88 per cent. of the material deposited from the large volume application was retained on the foliage. The results of the small volume test were vitiated by adverse wind conditions at the time of the experiments. A comparison of the amounts of copper deposited with those discharged from the nozzles showed that, in open ground, the loss by drift amounted to about 10 per cent. from the large volume application and to about 80 per cent. from the small volume application.

PLATE VII



The nozzle assembly of the air-flow mist sprayer.

PLATE VIII



Burgundy mixture deposits on potato leaves.

261	0.1 %	Cu, hydraulic sprayer,	98	gal. per acre.
153	0.25	" " "	"	" "
40	0.25	" " "	45	" "
306	0.5	" " "	"	" "
290	1.25	" " "	"	" "
336	1.25	" air-flow mist sprayer, 40	"	" "

Discussion.

In all three methods of application, most of the copper was deposited on the upper surfaces of the leaves. Large and Taylor (4), when reporting the results of small volume potato spraying with copper and DDT, have pointed out that while coverage of the upper leaf surfaces only may be sufficient for the control of mobile, biting insects, deposits on the undersides are desirable for the control of blight. No attempt was made in the present trials to correlate the levels of deposits with blight control.

The spraying operations covered three days, with an increase in the wind velocity on the third day, and the only valid comparisons that can be made are between treatments 1, 2, 3 and 4 and between 6 and 7. In both the large and small volume spraying, it will be seen that an increase in the copper concentration of the spray fluid gave an approximately proportionate increase in the amount of copper retained by the foliage and that, at the same copper concentration, the deposit from the large volume application was approximately double that from the small volume application. These relationships may, however, be fortuitous and would not necessarily be maintained in comparisons between different copper formulations or under different conditions of application. The effect of using the air-flow method was striking, the deposit obtained being appreciably greater than that given by small volume hydraulic application under similar conditions.

In experiments in open ground an appreciably greater percentage loss by drift was recorded from the small volume application than from the large volume application. Within the crop, however, the drift effect will be much reduced and, even with small volume application, most of the droplets may be expected to impact on the foliage.

Interesting differences were seen in the nature of dried deposits from the various applications, as shown by the plaster impressions. At the lower concentrations of copper, the film of fungicide, although varying in intensity, was continuous. At copper concentrations of 0.5 per cent. and above the deposits took the form of discrete spots, probably due to the use of too low a concentration of wetter. Large and Taylor (*loc. cit.*) have used an arbitrary scale for measuring coverage, a minimum of one hundred spots, each about 1 mm. diameter, per square inch being regarded as 100 per cent. cover. The coverage on plaques 290, 306 and 336 of Plate VIII was assessed by making *camera lucida* drawings of the deposits and measuring their areas. The values recorded, for regions taken at random, varied from 16 to 23 per cent. ; in the region of the most dense deposit on plaque 336 the coverage was less than 30 per cent. Further work is needed on the biological efficiencies of the types of deposit obtained from different treatments and on the minimum level of deposit required for blight control.

DDT DEPOSITS ON APPLE TREES.

Materials and Methods.

Trials with DDT were carried out in 1954 on Worcester Pearmain and Cox's Orange Pippin trees spaced 21' apart in the rows. The DDT used was a benzene-sulphite lye emulsion applied at a concentration of 0.05 per cent. DDT with 0.025 per cent. dioctyl sodium sulphosuccinate wetting agent.

The spraying methods used were :—

- (1) "Run-off" application by hand lance at 300 lb. per sq. in. flow pressure through three nozzles with short range swirl plates and 5/64" diameter disc apertures, the volume applied being approximately 600 gal. per acre.
- (2) Small-volume automatic mist-spraying by an experimental air-flow machine (1) using approximately 60 gal. per acre.

Further differences between the two methods must be emphasised. In the hand spraying method, a large volume of spray liquid was applied from several different directions until all target surfaces were wet to the point of run-off. In the mist spraying method, the trees were sprayed with and against the wind using a smaller volume of liquid for a limited period only. Another important factor was that while the large spray droplets from the hand lance covered an impact area of approximately 2 sq. ft. at the rate of 8 gal. per minute, the smaller ones from the mist sprayer, at the same distance, covered 15 sq. ft. at 3 gal. per minute. The paths of the droplets from the lance were approximately parallel while those from the mist sprayer were divergent, the volume impacting a unit area decreasing with distance from the discharge port.

Details of the trials are shown in Table II and of the lay-out in Fig. 1.

TABLE II.
LARGE AND SMALL VOLUME SPRAYING OF APPLE TREES.

Trial	Variety	Spraying date	Approx. bud stage	Wind speed	Treatment
A	Worcester	15/4/54	Bud-burst	12-14 m.p.h. gusting to 30 m.p.h.	(a) hand sprayed (b) drift from (a) (c) mist sprayed (d) drift from (c) (e) unsprayed
B	Cox	11/5/54	Blossom	3-8 m.p.h. gusting to 15 m.p.h.	(a) hand sprayed (b) drift from (a) (c) mist sprayed (d) drift from (c) (e) unsprayed
C	Cox	2/6/54	Fortnight after petal-fall	8-9 m.p.h. gusting to 18 m.p.h.	(a) hand sprayed (b) drift from (a) (c) mist sprayed (d) drift from (c) (e) unsprayed

Sampling and Analysis.

Whole fruit buds were taken at bud-burst, individual flowers and leaves at blossom time, and fruitlets and leaves at the post-blossom stage. Control samples were taken before spraying commenced and sprayed samples immediately after the deposits had dried. The samples, each of ten portions of plant material, were taken from ten positions in each tree (Fig. 2) in order to show possible differences in the levels of deposits between the windward and leeward sides, and between different positions within the sprayed and the neighbouring trees subjected to spray drift.

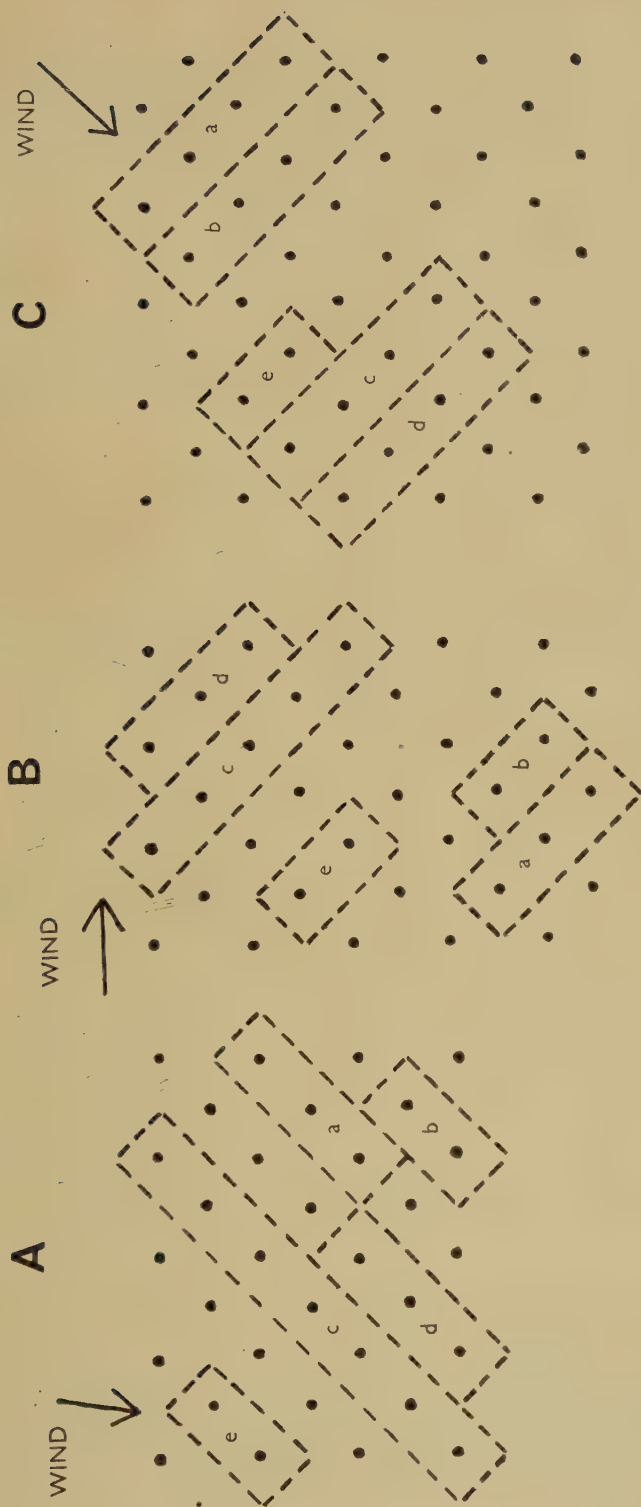


Fig. 1. Lay-out of DDT Trials.

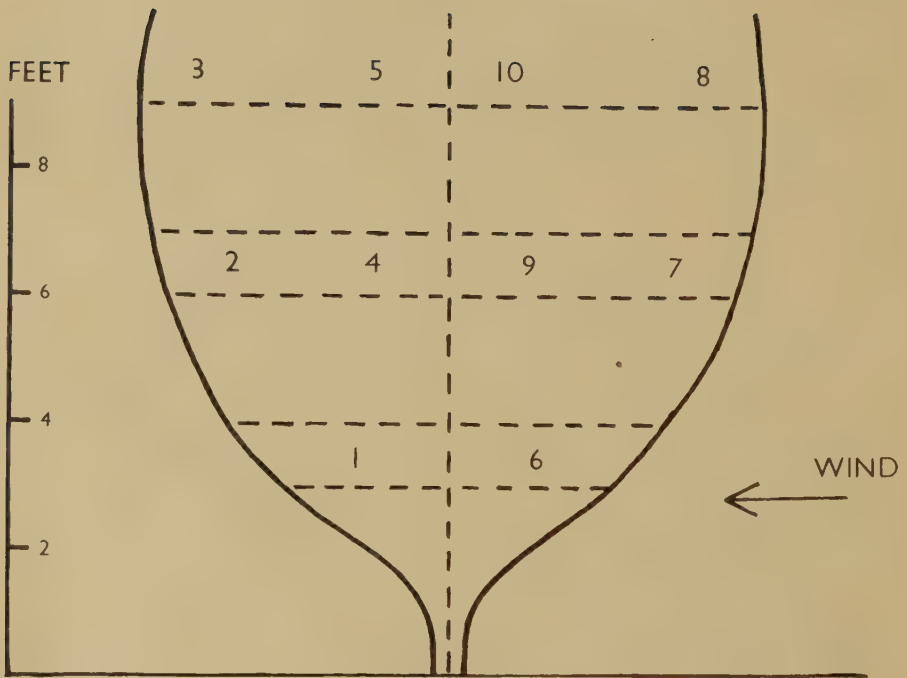


Fig. 2. Sampling Positions in Tree.

The samples were air-dried and then stored, in tubes, in desiccators. Averages of 20 buds, 50 flowers, 20 fruitlets and 1 g. of (dry) leaves were taken for analysis by the method of Martin and Batt (5) using the photoelectric absorptiometer and standard curve. The results are given in Tables III and IV.

TABLE III.
DDT DEPOSITS ON FRUITBUDS, FLOWERS AND FRUITLETS
AFTER DIFFERENT METHODS OF APPLICATION.

Position in tree	(a) Hand sprayed	(b) Drift from (a)	(c) Mist sprayed	(d) Drift from (c)
A. <i>Bud Burst Stage</i> μ g. DDT per bud—				
1	9.3	3.0	2.2	nil
2	12.3	4.5	2.4	nil
3	11.5	6.8	1.6	nil
4	12.8	4.6	2.0	nil
5	15.1	8.7	1.7	nil
6	22.3	5.4	2.3	nil
7	8.5	7.2	1.1	trace
8	7.9	10.4	1.9	nil
9	14.4	4.4	1.4	trace
10	14.1	6.0	1.1	nil
B. <i>Blossom Stage</i> μ g. DDT per flower—				
1	14.0	0.4	2.1	0.2
2	16.0	0.4	2.0	0.4
3	9.8	0.2	0.9	0.4
4	15.6	0.3	1.3	0.4
5	9.4	0.2	0.9	0.3
6	19.9	1.5	1.4	0.4
7	19.2	1.2	1.6	0.4
8	14.2	0.5	1.0	0.6
9	21.1	0.6	2.3	0.5
10	15.1	0.8	1.5	0.4
C. <i>Fruitlet Stage</i> μ g. DDT per fruitlet—				
1	26.6	1.7	3.5	0.5
2	24.0	1.2	2.5	0.4
3	21.8	0.9	1.3	0.9
4	25.0	1.4	2.0	0.4
5	26.5	1.3	2.7	0.5
6	11.3	1.2	2.3	0.5
7	29.2	1.4	3.1	0.6
8	20.0	2.0	1.9	0.6
9	21.3	2.1	1.9	0.5
10	22.3	1.5	2.4	0.6

Unsprayed controls (e) at all stages : DDT nil.

Weights : buds 35-79 mg., flowers 17-21 mg., fruitlets 21-83 mg.

Discussion.

The determinations of DDT in the leaves were carried out on a weight basis, on the assumption that weight would be proportional to surface area. The dried leaves were powdered before extraction to ensure that any DDT that might have passed within the tissues would be recovered.

The results obtained relate only to the particular methods of application used and to the environmental conditions at the time of the experiments. As expected, the deposits from the hand spraying were appreciably higher than

TABLE IV.

DDT DEPOSITS ON LEAVES AFTER DIFFERENT METHODS OF APPLICATION.

Position in tree	(a) Hand sprayed	(b) Drift from (a)	(c) Mist sprayed	(d) Drift from (c)
B. Blossom Stage μ g. DDT per g. dried leaves—				
1	723	44	160	17
2	—	47	151	23
3	689	24	118	27
4	803	36	135	26
5	638	24	133	28
6	726	183	151	41
7	845	138	108	55
8	637	80	133	108
9	—	70	85	40
10	622	165	129	36
C. Fruitlet Stage μ g. DDT per g. dried leaves—				
1	695	49	115	24
2	725	74	140	22
3	595	59	100	19
4	684	37	98	20
5	655	36	124	16
6	540	80	83	32
7	540	100	88	29
8	470	75	94	33
9	490	50	120	20
10	495	80	69	20

Unsprayed controls (e) at both stages : DDT nil.

those from the mist application. It is interesting to note that the ratios of the deposits from the hand spraying to those from the mist spraying are greater for the buds, flowers and fruitlets than for the leaves. This may reflect a proportionately greater run-off from the leaf surfaces.

At the bud-burst stage, the deposit from the mist spraying was appreciably less than that from the drift from the hand spraying; at the later stages it exceeded but did not differ appreciably from the drift deposit from the high volume application. Under the conditions of the experiments, the effect of mist spraying has thus been approximately analogous to the effect produced by drift from spraying to run-off.

The extent to which targets are exposed and the areas they present to the spray droplets will influence the amount of deposit. Higher deposits, due to drift from hand spraying, were found on the buds than on the flowers or fruitlets. This may have been due to wind conditions and to the fact that the buds were exposed singly, whereas many of the flowers and fruitlets were protected within the clusters. By contrast no deposit due to drift from mist spraying was found on the buds, whereas appreciable amounts were found on the flowers and fruitlets. It seems likely that the small droplets were carried round the buds by the slip-stream, but readily penetrated and impacted on the larger, open clusters. Turbulence in the air stream, set up by the larger targets, may also have contributed to the higher deposits; this factor is likely to be particularly important in the air-flow mist spraying of foliage. Evenness of deposition was rather more marked with the mist than with the hand spraying, and no appreciable differences were seen between the deposits at points within, or on the windward and leeward sides of the trees.

Summary.

- (1) Experiments are described on the application of copper to potato plants using large and small volume hydraulic and small volume air-flow spraying, and of DDT to apple trees using lance and air-flow methods.
- (2) The deposits, including those from drift, determined by chemical analysis of the sprayed plants are discussed in relation to the methods of application used.

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SPRAY APPLICATION PROBLEMS:

XVI. THE EVALUATION OF AN AVERAGE DROPLET DIAMETER IN SPRAYS.

By C. G. L. FURMIDGE.

The size of the droplets composing a spray usually varies over a very wide range. Droplets formed from a high-speed rotating disc are fairly uniform in size but any spray formed by liquid pressure or by air flow may contain droplets whose diameters vary between one micron and a few hundred microns. Nevertheless it is customary to refer to a spray in terms of an average droplet diameter although with such a range of actual drop diameters it is difficult to give this average diameter any physical significance. The simple arithmetic mean of the drop diameters gives an indication of the spray fineness or quality of the liquid atomisation, but in studying the performance of a particular nozzle it is most important to know how the volume of the spray is distributed. Thus, for the study of sprays used for the application of plant protection materials, an expression of the average droplet diameter is required which, as far as possible, will indicate the variation in both the volume of spray and the actual droplet size.

Experimental.

The spray pattern used in this work was obtained with a $\frac{1}{4}$ " B.S.P. nozzle fitted with a $\frac{2}{64}$ " disc and small-volume swirl plate (1) working at a pressure of 75 lb./sq. in. and with a flow rate of 7.5 fl. oz./min.; the nozzle was clamped horizontally two feet above the sampling board. Water was used as the spray material and the droplets were collected by exposing slides coated with magnesium oxide to the spray for a period of 2 sec.; the ratio of oxide-impression-size/droplet-size was taken to be 1.14 (2). The shape of the spray pattern was roughly an ellipse, with a major axis of $4\frac{1}{2}$ ft. and a minor axis of 4 ft. (Fig. 1); the horizontal distance of the nozzle from the first collecting slide was 6 in. In the absence of draughts, the spray pattern was assumed to be reversible about the major axis and the sampling was carried out on 64 slides placed to cover half the spray pattern. The contour diagram for this half was worked out and the other half of the pattern was constructed as the mirror image of the first.

The spray patterns in relation to the two important factors, volume of spray and arithmetic mean diameter of the droplets, are shown in the contour diagrams, Figs. 1 and 2 respectively.

Discussion.

By the introduction of an average droplet diameter, the actual spray composed of droplets of different sizes is in effect replaced by an imaginary spray whose droplets are all the same size and equal to the average value. One of the most common expressions used in agricultural sprays is the mass median diameter; calculated such that half the mass of the spray is contained in droplets with a smaller diameter and half the mass in droplets of greater diameter. The mass median diameter may be determined by computing the

volume of spray in each size class of droplets and plotting the percentage cumulative volume against the logarithm of the drop diameter on arithmetic probability paper. A reasonably straight line should be obtained and the mass median diameter may be read off the diameter axis at the point where the cumulative volume has the value 50%. This is illustrated in Table I, which gives the droplet frequency of two samples collected in the spray pattern.

TABLE I.
DROPLET FREQUENCY AND CUMULATIVE VOLUME OF SPRAY SAMPLES.

Droplet diameter (μ)	Sample No. 1.			Sample No. 2.		
	No. of droplets	Cumulative volume ($\mu^3 \times 10^{-4}$)	per cent. Cumulative volume (R)	No. of droplets	Cumulative volume ($\mu^3 \times 10^{-4}$)	per cent. Cumulative volume
0- 23 ..	1	0.196	0.002	2	0.391	0.008
23- 38 ..	3	4.892	0.052	17	27.006	0.558
38- 54 ..	8	47.177	0.503	14	101.004	2.086
54- 69 ..	20	297.791	3.172	20	351.618	7.263
69- 85 ..	22	836.273	8.908	41	1355.153	27.992
85-101 ..	34	2273.944	24.223	41	3088.814	63.802
101-116 ..	21	3684.141	39.245	18	4297.555	88.769
116-131 ..	17	5388.321	57.398	4	4698.538	97.052
131-147 ..	7	6387.505	68.042	1	4841.279	100.000
147-162 ..	10	8345.243	88.896			
162-178 ..	4	9387.598	100.000			

In Fig. 3 (curves A and B) the cumulative volume (R) is plotted against the logarithm of the droplet diameter for samples 1 and 2 respectively. These curves give the mass median diameter of sample 1 to be 118 μ and sample 2 to be 86 μ ; this is considerably higher than the arithmetic mean diameters whose values are 93 μ and 74 μ respectively. In calculating the arithmetic mean diameter, all the droplets make an equal contribution, whereas the contribution of the larger droplets to the mass median diameter is much greater than that of the smaller droplets owing to their very much larger mass. It might therefore be expected that the mass median diameter would provide some link between the actual volume of the spray and the actual droplet size. However, if Fig. 4, in which the spray pattern is plotted in terms of the mass median diameter, is compared with Figs. 1 and 2, it will be seen that there is virtually no similarity.

The number median diameter may be used in place of the mass median diameter; this is evaluated in a similar way using the cumulative percentage of the total number of droplets in each size class. The number median diameters for samples 1 and 2 above, given by curves A' and B', Fig. 3, are 86 μ and 72 μ

respectively. These figures are very close to the arithmetic mean diameters (93 and 74 μ); they would be equal if the droplet spectrum had a normal distribution.

An average droplet diameter may also be evaluated by considering an imaginary spray having the same total volume, total surface area, total radius or total number of droplets as the actual spray. In comparing the imaginary with the actual spray, only two of these four quantities can be equal at the same time; for example, if the total volumes and total surface areas are equated, neither the total radii, nor the total number of droplets will be equal in the two sprays.

In a study of fuel spray droplets, Sauter (3) found that the best average droplet diameter was given by assuming the total volume and total surface area of the imaginary and actual sprays to be equal. The value of the average diameter, known as the Sauter mean diameter (S.M.D.), is easily determined by dividing the volume by the surface area.

If the total volume of droplets in the imaginary spray is

$$V_0 = \frac{4}{3} \pi n_0 r_0^3 \dots\dots\dots 1$$

the total surface area will be

$$A_0 = 4\pi n_0 r_0^2 \dots\dots\dots 2$$

Dividing 1 by 2

$$2r_0 = d_0 = \frac{6V_0}{A_0} = \frac{6V_A}{A_A}$$

(V_A and A_A are the total volume and total surface area of the actual spray).

The spray pattern used in this work has been plotted in terms of the S.M.D. in Fig. 5. It will be seen that it also shows little similarity to the spray patterns shown in Figs. 1 and 2; the Sauter mean diameter is most usefully employed in the study of fuel sprays since the volume and surface area of the spray are the most significant quantities in the combustion process.

Since the significant factors in this study are volume and radius, an average droplet diameter may be evaluated, as above, by equating the total volume and also the total radius of the imaginary and the actual sprays. The total volume of droplets in the imaginary spray will then be :—

$$V_1 = \frac{4}{3} \pi n_1 r_1^3 \dots\dots\dots 3$$

and the total radius,

$$R_1 = n_1 r_1 \dots\dots\dots 4$$

Dividing 3 by 4,

$$4r_1^2 = \frac{3V_1}{\pi R_1} \quad \text{or} \quad d_1 = \sqrt{\frac{6V_1}{C_1}} = \sqrt{\frac{6V_A}{C_A}}$$

(C_1 and C_A are the total circumferences of the droplets in the imaginary and the actual sprays).

An average diameter may also be evaluated by equating the total volume and the total number of droplets in the two sprays.

The total volume of the imaginary spray will be :—

$$V_2 = \frac{4}{3} \pi n_2 r_2^3 \dots\dots\dots 5$$

and the total number $N_2 = n_2 \dots\dots\dots 6$

$$\text{Thus } 8r_2^3 = \frac{6V_2}{\pi N_2} \text{ and } d_2 = \sqrt[3]{\frac{6V_2}{\pi N_2}} = \sqrt[3]{\frac{6V_A}{\pi N_A}}$$

where N_A is the total number of drops in the actual spray.

The spray patterns obtained from these average diameters are shown in Figs. 6 and 7 respectively ; Fig. 7 shows particularly good agreement with the spray patterns of volume and diameter distributions in Figs. 1 and 2. This agreement is illustrated in Fig. 8 which shows cross sections from A to B Fig. 1 (curve X), Fig. 2 (curve Y) and Fig. 7 (curve Z). In general shape, curve Z represents a reasonably accurate combination of curves X and Y ; its most serious limitation lies in the rather large values obtained for the average diameter when the actual volume of spray is very small ; this may be seen as curves X and Z approach B.

Whilst it is impossible to obtain a single figure for the average diameter which accurately combines the volume and the arithmetic mean droplet

diameter of a spray, the expression $\sqrt[3]{\frac{6V}{\pi N}}$ gives the nearest approximation

to this ideal of any of the expressions tested. The value of the average diameter calculated in this way will always be larger than the arithmetic mean diameter, but it will give an estimate of spray fineness and it will also give an indication of the volume distribution in a spray.

Summary.

The most important factors to be considered in evaluating an average droplet diameter for horticultural sprays are the volume of the spray and the actual droplet size.

Several methods of calculating an average diameter have been tested, including the mass median diameter and the Sauter mean diameter ; contour diagrams of the spray pattern produced by these figures have been compared with the spray distribution pattern of volume and of arithmetic mean diameter.

The most satisfactory average droplet diameter (d_0) was found to be given

by $d_0 = \sqrt[3]{\frac{6V}{\pi N}}$, where V is the total volume of the droplets in the sample,

and N is their total number.

Acknowledgments.

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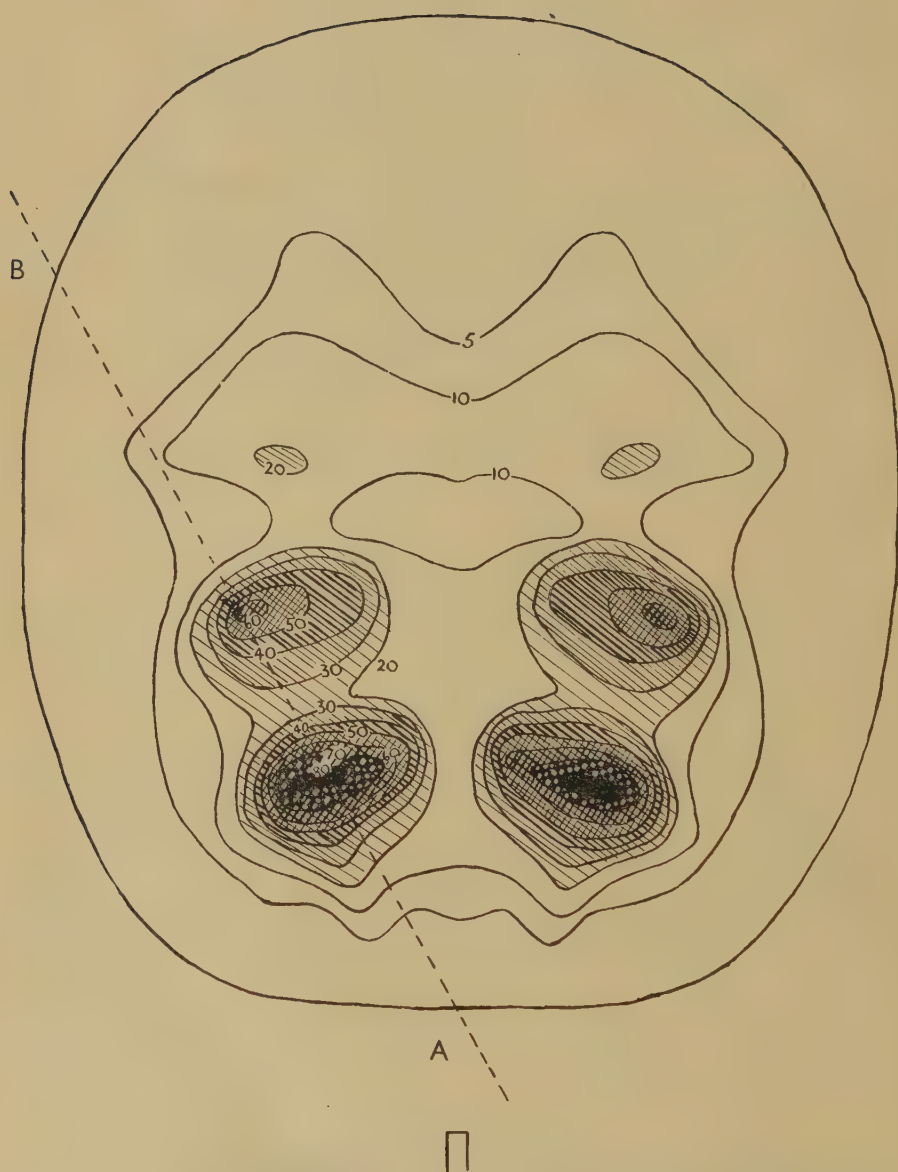


Fig. 1. Spray pattern : Distribution of volume of spray, ml. $\times 10^4$ per sq. cm. in 2 secs.

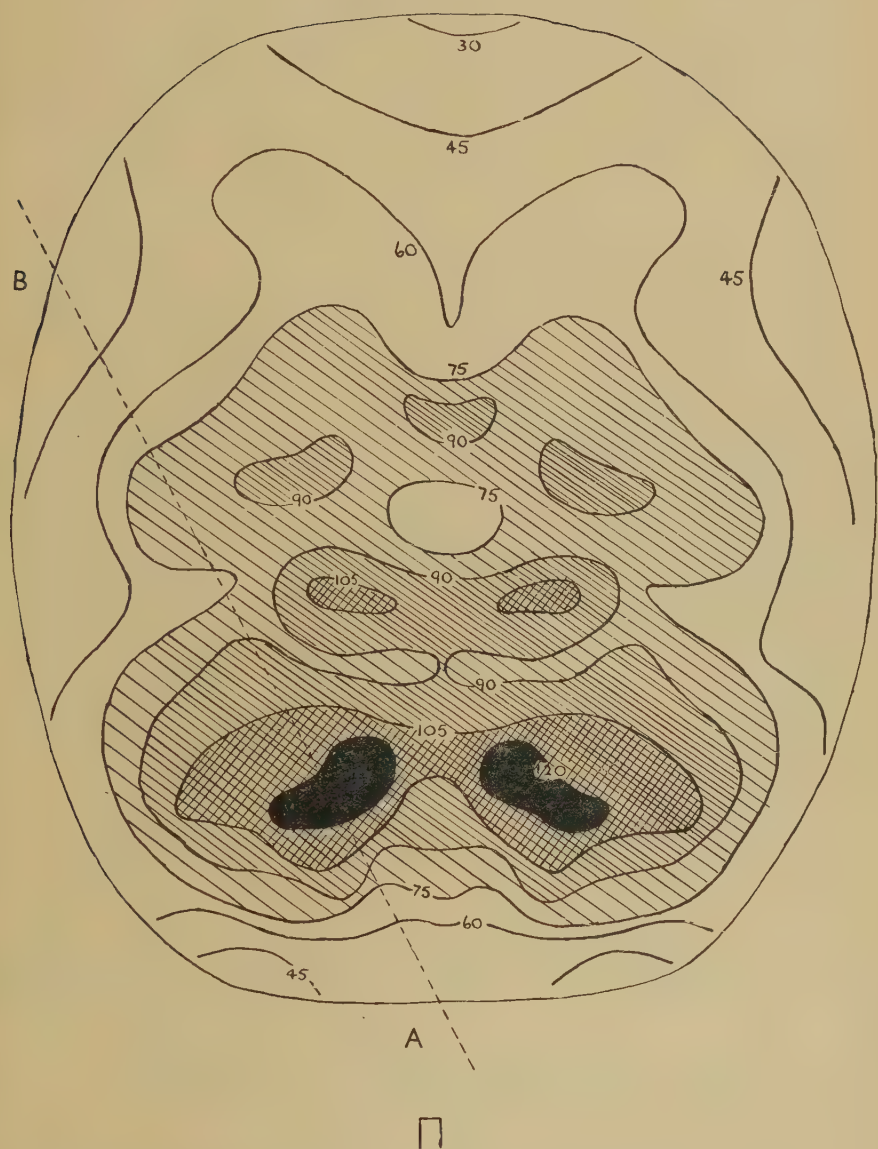


Fig. 2. Spray pattern : Distribution of arithmetic mean diameters (cm. $\times 10^4$).

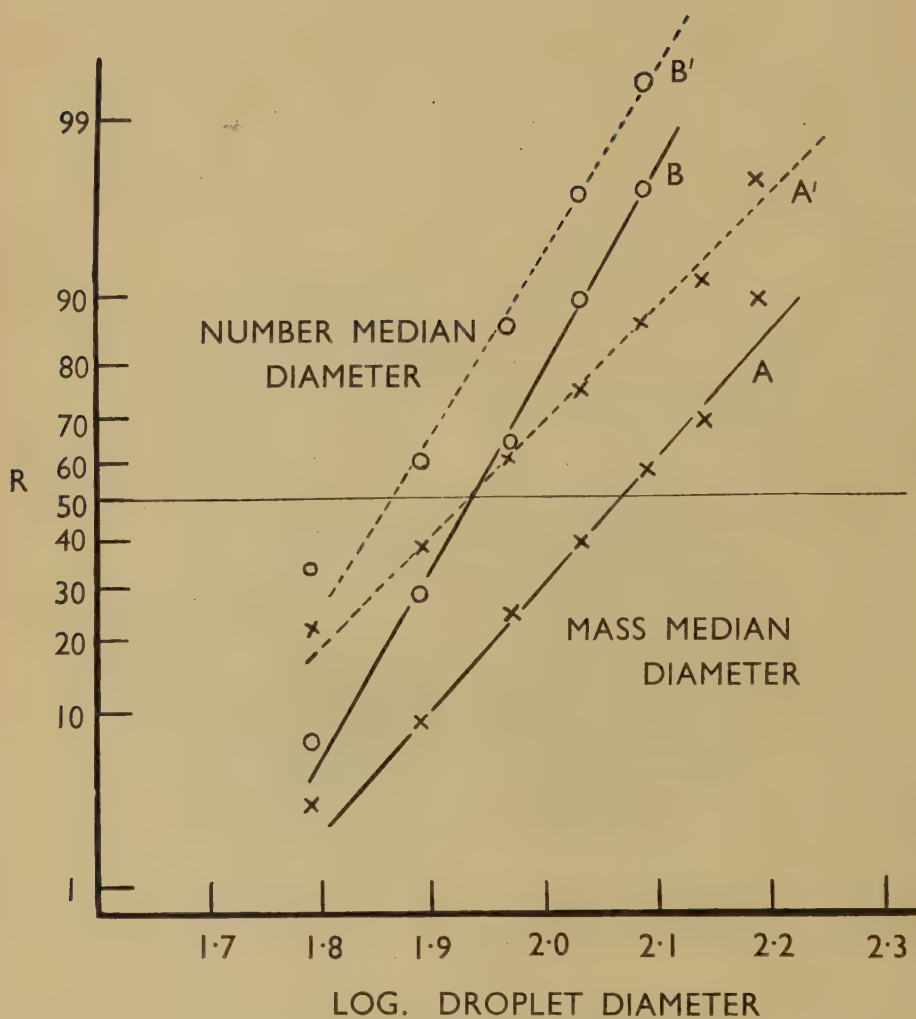


Fig. 3. Evaluation of mass and number median diameters.

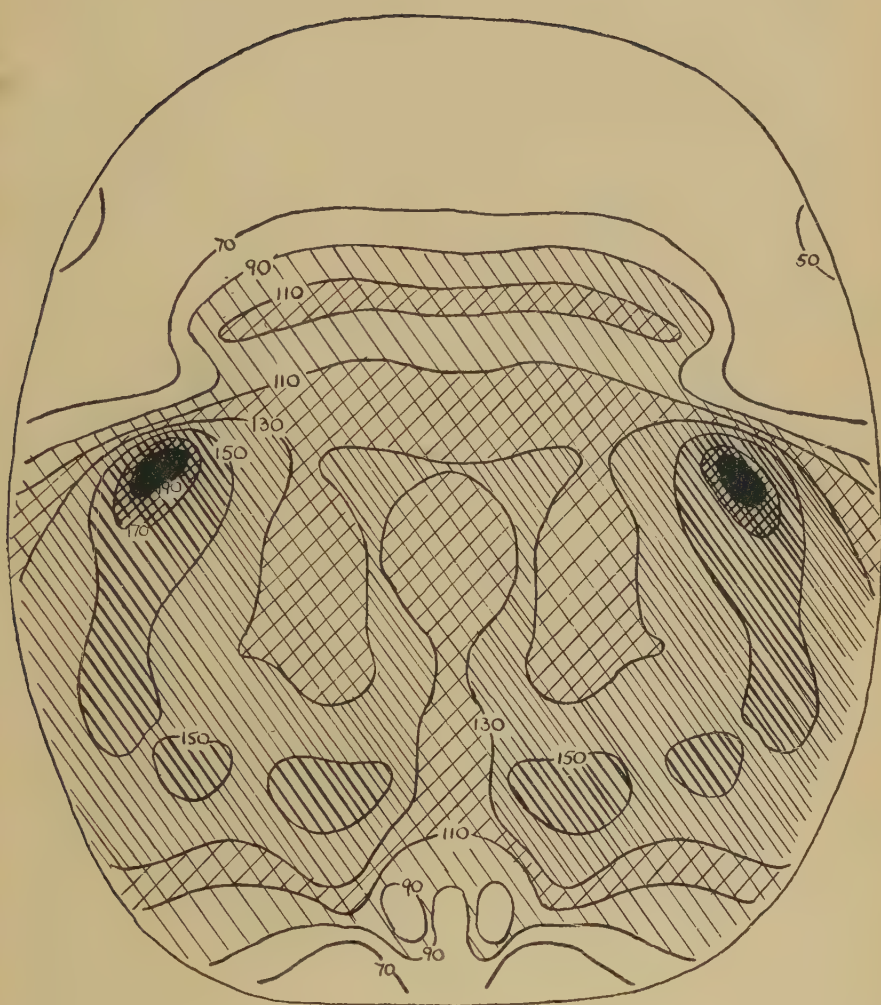


Fig. 4. Spray pattern : Distribution of mass median diameters. (cm. $\times 10^4$).

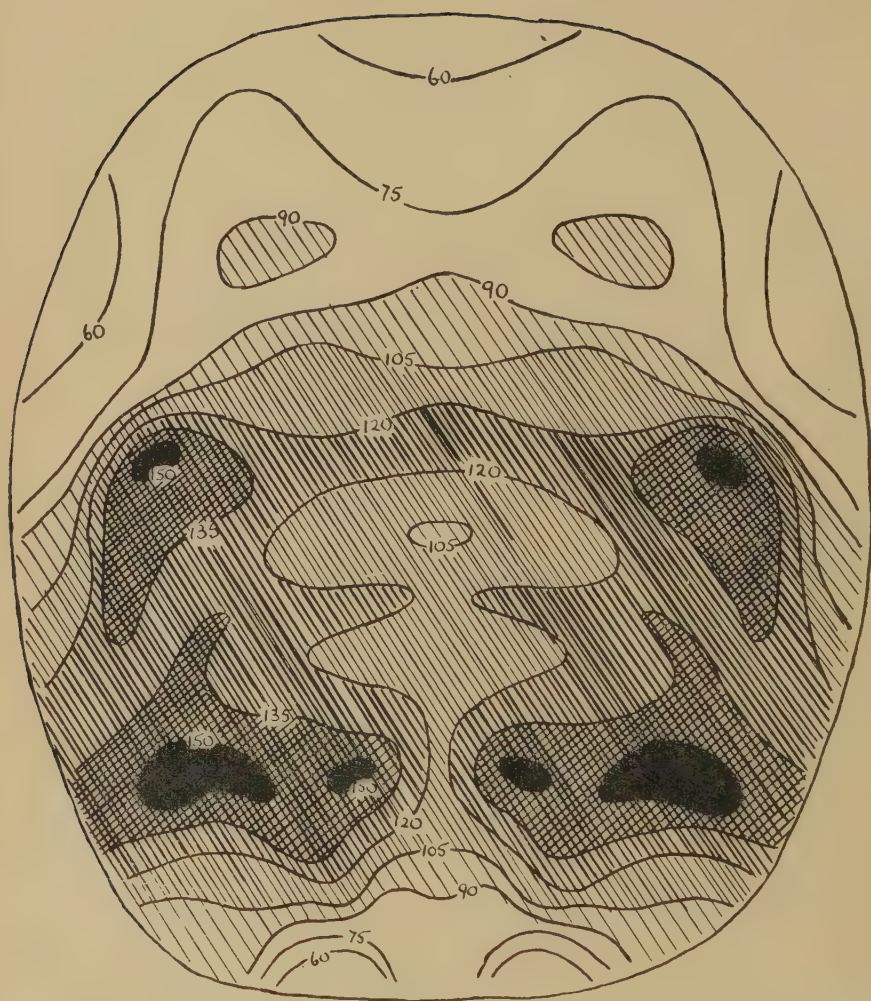
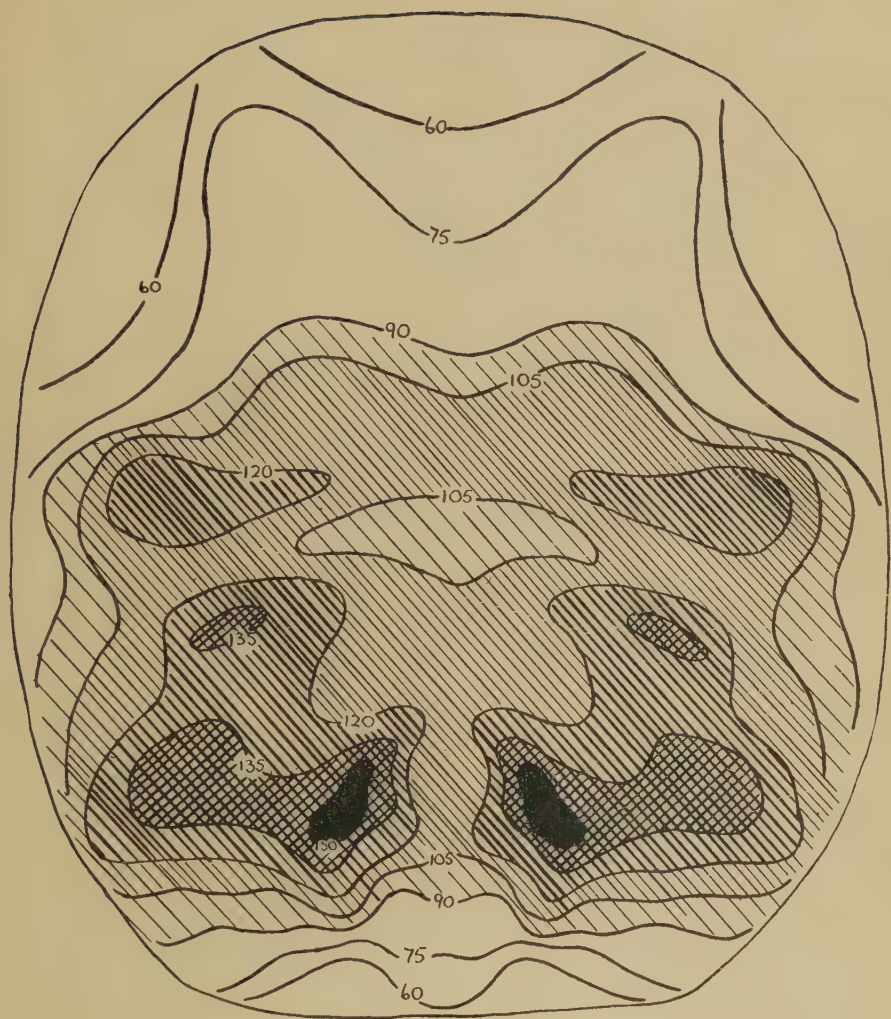


Fig. 5. Spray pattern : Distribution of Sauter mean diameters. . . . $d_s = \frac{6V}{A}$ (cm. $\times 10^4$).



□

Fig. 6. Spray pattern : Distribution of the mean diameters. $d_0 = \sqrt{\frac{6V}{C}}$ (cm. $\times 10^4$).

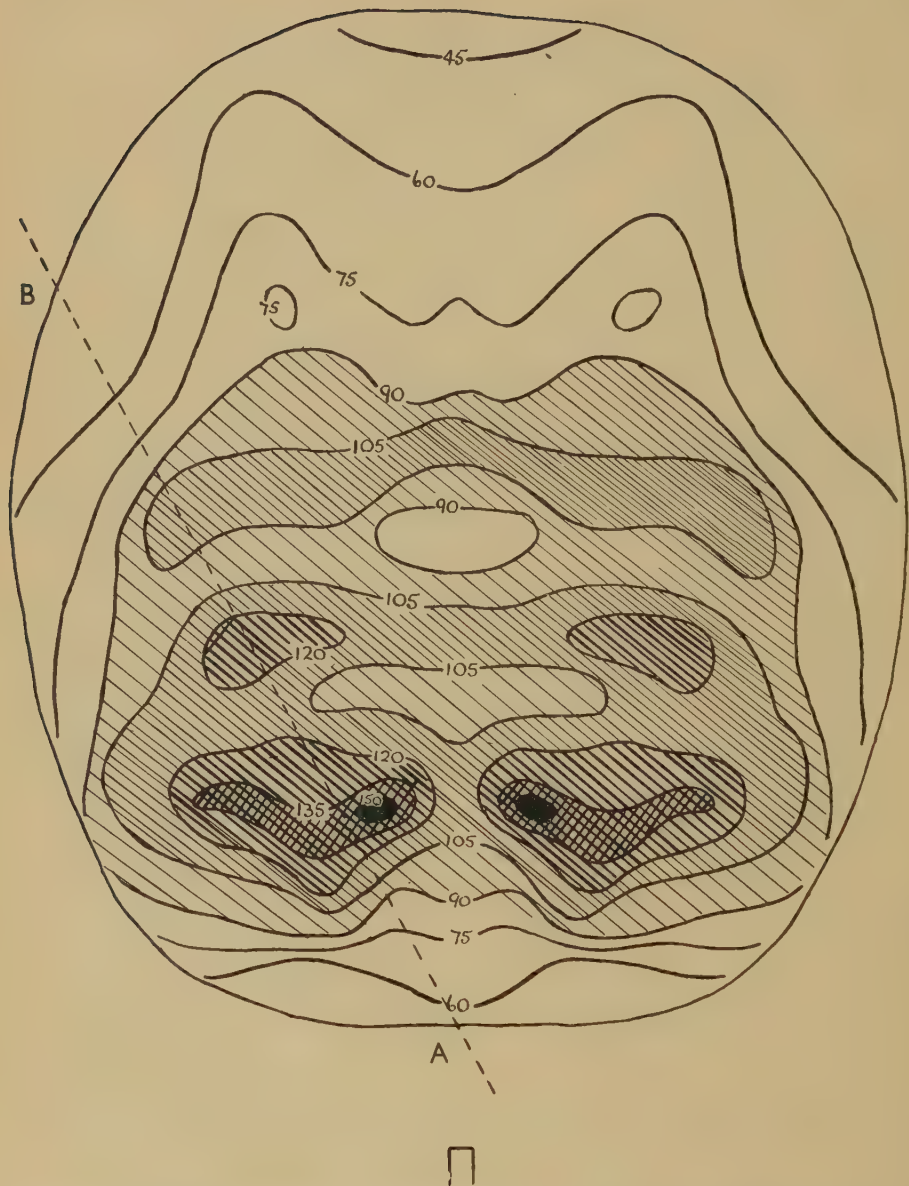


Fig. 7. Spray pattern : Distribution of the mean diameters. $d_0 = \sqrt[3]{\frac{6V}{\pi N}}$ (cm. $\times 10^4$).

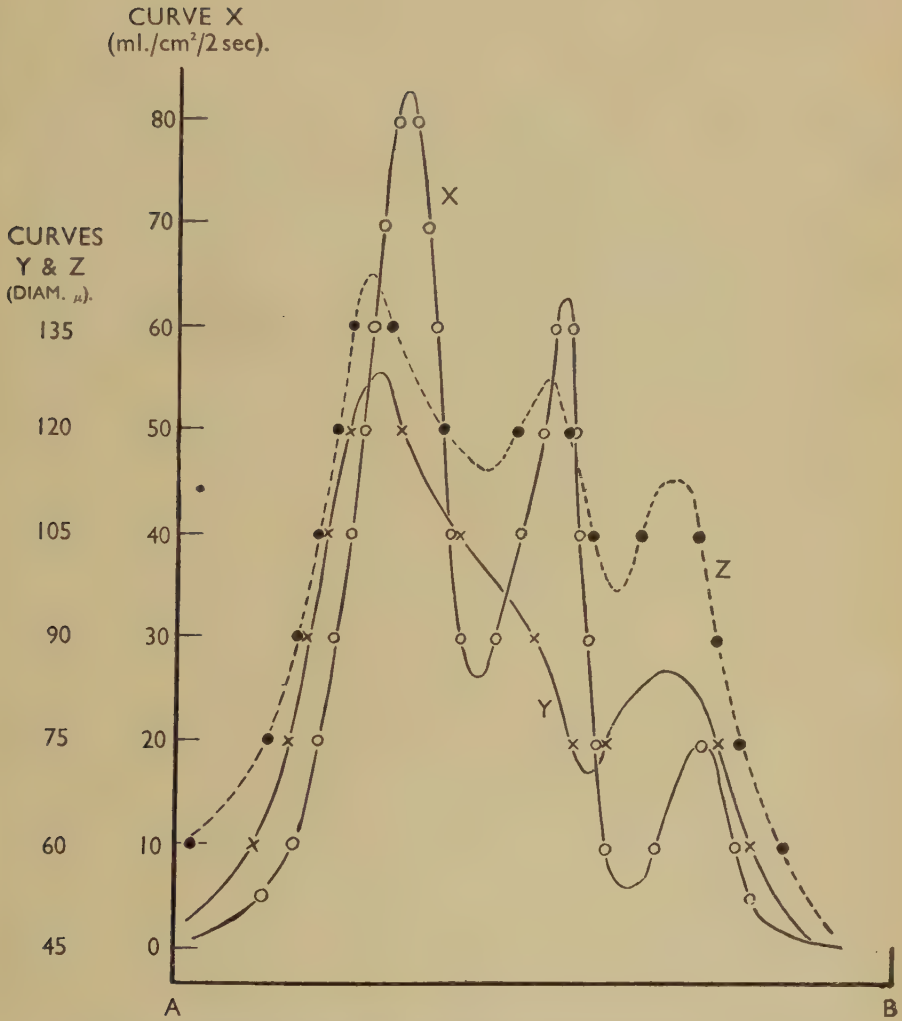


Fig. 8. Comparison of the variation of volume and arithmetic mean diameter with the mean diameter..... $d_0 = \sqrt[3]{\frac{6V}{\pi N}}$

SPRAY APPLICATION PROBLEMS :

XVII. THE MEASUREMENT OF SPRAY DROPLET SIZE IN THE FIELD.

By C. G. L. FURMIDGE.

The measurement of spray droplet size is a problem of fundamental importance both in the development of spray machinery and in the evaluation of the efficiency of spray materials in practice. Many methods of droplet assessment have been employed in field work but there is little information on the accuracy of such methods under practical conditions. There are considerable discrepancies in the published work on some of these methods. For example, when a droplet falls on to a slide coated with magnesium oxide, an impression is produced in the oxide layer : it is assumed that the size of this impression bears a direct relationship to the size of the drop, but the factor relating impression size to drop size has varied with different workers from 1.0 to 1.2. Besides these quantitative errors, there remains the important question of whether the various methods of collection and estimation give an accurate picture of the distribution of droplet sizes in the actual spray. It is the purpose of this paper to show how the accuracy of a given method may be assessed and to indicate the degree of accuracy attainable by the different methods that may be employed.

Available Methods.

No direct method for the measurement of spray droplets has yet been developed which is of use in the field. Such a method entails the collection and preservation of the drops in their original spherical form which, whilst ideal for small-scale laboratory work, is too difficult for use in field operations. The most satisfactory methods available are those in which the spray is collected on a suitable surface upon which the droplets form individual impressions or stains whose size bears a direct relationship to the size of the droplets. In the case of the stain methods, either a dye must be added to the spray, or it must be possible to develop the stains by treating the exposed surface with a suitable chemical ; for example, the stains from a copper spray may be developed by a solution of sodium diethyldithiocarbamate (1). The collecting surface for the stain method is usually an absorbent or semi-absorbent paper : the impression methods usually use slides coated either with magnesium oxide, prepared by holding the slide in burning magnesium ribbon, or with soot from a kerosene-soaked wick. The actual measurement of the stain or impression size may be carried out directly with a microscope or from photomicrographs of the collecting surface. A method for the mechanical estimation and counting of such deposits has recently been described by Trickett and Courshee (2).

Experimental.

In the present work, magnesium oxide has been used to illustrate the impression method and the stain method has been studied using various types of paper surfaces, a clean glass surface, and plaster of Paris. The plaster

surfaces were prepared from pure calcium sulphate, mixed to a thick paste with water and then pressed into a thin sheet between two glass plates ; when almost dry, the upper plate was removed and the plaster cut into pieces, the size of microscope slides.

Droplets were usually formed from a spinning disc, diameter 9 cm. and with variable speed up to 3,000 r.p.m. ; the flow of liquid on to the disc was controlled at 80 ml. per minute. The collecting surfaces were enclosed in a metal tray, fitted with a shutter, so that only a small portion of the spray was collected.

In order to compare drop size with stain size, it was necessary to employ a standard method to collect and measure the actual droplets in the spray. The method finally employed was that described by Courshee and Byass (3) who allowed the drops to fall into a cell, the base of which was covered by a thin layer of grease prepared by mixing 24% vaseline with 76% medicinal paraffin. Since small droplets are prone to considerable evaporation losses (see Courshee and Byass), it is necessary to cover the drops with medicinal paraffin as soon as possible after landing. Once covered in this way they were found to be perfectly stable for a period up to 48 hours after collection, and since they were completely immersed in the oil, they remained perfectly spherical (Plate IX (a)). In practice, it was found possible to cover the sample drops with medicinal paraffin within 10 sec. of their collection ; hence no evaporation corrections were necessary for measuring the drop diameter.

The experiments were carried out by exposing the oil cell to the spray droplets for a few seconds, and then replacing it by the surfaces under test. The diameter of about 200 drops or stains was then measured by a microscope, using an eyepiece graticule and a magnification of either 50 or 100, depending upon the size of the drops or stains.

Theoretical.

The most important factors that may influence stain size are (a) the absorbing power of the collecting surface, (b) the momentum of the drops when they strike the surface, and (c) the angle of impingement on the surface. Factor (a) will vary with the nature of the surface and, as seen from Plate IX, considerable differences in stain size are found using different surfaces. Also important in this factor will be the volatility, the viscosity and the surface tension of the spray fluid, but this factor will be constant for any one spray on a given collecting surface. Factor (b), however, will vary with both the size and the speed of the drops, and the stain size/drop size ratio may be affected. The operation of this factor renders it useless merely to compare the arithmetic mean of the diameter of the droplets collected in oil with the diameter of the stains produced on the surface under test : it is necessary to be able to compare the actual size distribution curves for the drops in oil with those for the stains.

The ordinary frequency curve where the droplet (or stain) size is plotted directly against the number of droplets of that size is usually unsymmetrical (see Figs. 1 and 2) and curves of this type are difficult to compare accurately one with another. The frequency curve becomes more symmetrical, however, when the logarithm of the droplet size is employed. Then, by plotting the logarithm of droplet diameter against the percentage cumulative values of the volume of the droplets with diameters equal to and greater than the diameter

given by the ordinate, a straight line may be obtained for the size distribution in the liquid spray.

Several equations for the drop size distribution in sprays have been developed along these lines (4). Both Watson (5) and Joyce (6) have used the Rosin-Rammler relationship (originally derived for particle size distribution in powders) to describe the droplet size distribution in sprays, and because of its simplicity in application it was used in the present work. It may be expressed in the form :—

$$R = e^{-\left(\frac{x}{\bar{x}}\right)^n} \dots\dots\dots (1)$$

where R is the cumulative volume of droplets of size equal to and greater than x , expressed as a ratio of the total volume of the sample ; x is the droplet diameter ; $\bar{x}$ and n are constants.

From equation (1) ; $\log \frac{1}{R} = \log \left(e^{\frac{x}{\bar{x}}} \right)^n$

$$\text{and } \log \log \frac{1}{R} = n \log x - n \log \bar{x} \dots\dots\dots (2)$$

Thus, since $n \log \bar{x}$ is a constant, when $\log \log \frac{1}{R}$ is plotted against $\log x$,

the results should lie on a straight line of slope n . Since this gives a direct relation between R and x , the line obtained will be characteristic of the drop size distribution in a given spray and the only effect of altering the relative sizes of R and x will be to alter the magnitude of the constant $n \log \bar{x}$. Thus if the stain size distribution is similar to the drop size distribution, the values calculated from the stain sizes should give a straight line parallel to the line given by the standard drops in oil. Then, if x_1 is the droplet diameter in oil and x_2 is the stain diameter :—

$$\log \log \frac{1}{R_1} = n \log x_1 - k_1 \text{ for the drops in oil}$$

$$\text{and } \log \log \frac{1}{R_2} = n \log x_2 - k_2 \text{ for the stains.}$$

$$\text{When } \log \log \frac{1}{R_1} = \log \log \frac{1}{R_2} = 0$$

the ratio stain size/drop size $\frac{x_2}{x_1} = \text{antilog } (k_2 - k_1)$; and $(k_2 - k_1)$ may be read directly off the ordinate.

The Rosin-Rammler expression implies the existence of droplets of all sizes from zero to infinity and so it does not agree exactly with the drop size distribution in a spray. Instead of a perfect straight line the curves obtained are of the type shown in Figs. 3 and 4.

Results.

Effect of the Nature of the Collecting Surface.

Several collecting surfaces have been employed in this work and it would appear that reasonably circular stains are produced on surfaces which are homogeneous and uniform (Plate IX). A high absorption of the droplet into the collecting material is not necessary: for example, a clean glass surface can produce perfect stains under ideal, still conditions (Plate IX (b)). In the field, however, such conditions are seldom encountered and it is preferable to use a material which absorbs the drops immediately on contact. Suitable in this respect are plaster of Paris and most of the filter papers tested.

The spray frequency curves for some of these surfaces are compared with the actual spray frequencies in Fig. 1, obtained using sprays of an aqueous solution of the red dyestuff rhodamine, and in Fig. 2 using an aqueous solution of copper sulphate, developed with a solution of sodium diethyldithiocarbamate.

Using the Rosin-Rammler expression, the same results are shown in Figs. 3 and 4 and it will be seen that there is good agreement between the spray distribution obtained from the stain sizes and that from the droplets in oil. Although the plaster surface produces useful stains with the copper sulphate spray, it was found impossible to use this surface with the rhodamine spray, since the stains from the latter spread rapidly. From the results with No. 120 reaction paper, it will be seen that the stain size/drop size ratio varies for this surface also, since in the case of the copper sulphate spray it is 7.33 and in the case of the rhodamine spray it is 4.05. This is due to the fact that the rhodamine dye produces a stain directly, whereas the copper stain has to be developed by treatment with another solution. This after-treatment causes the original stain to spread further and therefore it is essential that the after-treatment given to all the collecting surfaces should be identical. Since the drop size/stain size ratio may also vary with the viscosity, volatility and surface tension of the spray fluid, it is necessary to evaluate this ratio for every type of spray used.

Effect of the Momentum of the Droplets on Impact.

This effect was studied by using a range of droplet sizes; as the droplets become larger their momentum on impact increases. It was found that, above a critical value, the momentum of the drop had little effect on the drop size/stain size ratio: the ratio was reasonably constant for drops varying in diameter from about 60 to 300 μ , and the stain size distribution curves showed good agreement with the actual drop size distributions. Using drops of diameter less than 50 μ , however, the size distribution curves did not agree and the drop size/stain size ratio became progressively greater as the droplet size decreased. This is illustrated in Fig. 5, where curves D, E and F show good agreement for drops whose size lies between 100 and 150 μ , whereas curves G, H and K show no agreement in the drop and stain size distributions for drops between 20 and 70 μ diameter and a drop size/stain size ratio cannot accurately be determined.

This effect is most noticeable when an absorbent collecting surface is employed. On the other hand perfectly satisfactory stains from drops as small as 10 μ may be obtained on clean glass surfaces and reasonably satisfactory impressions may be obtained using magnesium oxide slides.

Effect of the Angle of Impingement of Drops.

When drops strike the collecting surface at angles less than 90° the stains formed tend to be elliptical rather than circular. This tendency may be decreased by increasing the absorption of the droplet at the collecting surface ; for example, compared with a non-absorbing glass surface the effect on a highly absorbent surface, such as plaster of Paris or Whatman's No. 120 reaction paper, is hardly noticeable. In the latter cases, if the smallest diameter of any elliptical stains is measured the stain size distribution still agrees with the actual drop size distribution, but in cases where there is serious distortion no such agreement exists.

The angle of impingement has also a considerable effect on impressions in magnesium oxide ; this is illustrated in Fig. 6. Curves R and S show good agreement for the size distribution between drop size and impression size ; they were obtained from drops impinging at an angle of 60° to the horizontal. In curves R_1 and S_1 in which the angle was reduced to 40° the size distribution of the oxide impressions no longer agrees with drop size distribution. On reducing the angle of impingement to 30° , no impressions whatsoever were formed in the oxide film as all the droplets bounced off, presumably due to the cushioning effect of the film.

Discussion.

Drops in Oil. This method, as described above, has proved admirable for drop size estimations in the laboratory, but since it entails covering the collected sample of drops immediately with medicinal paraffin it is useless for field work.

Stains on Glass. This is also a very good method under ideal laboratory conditions. It is less troublesome than collecting the droplets in oil but it may be used only for drops impinging normally to the surface and the spray must be sufficiently coloured to produce a distinct stain ; development of the stain after collection is impracticable. Under ideal conditions the stain size/drop size ratio is constant ; for an aqueous spray containing rhodamine the value is 2.46.

Impressions in Magnesium Oxide. This is a popular method of spray estimation since it provides a permanent record and may be used with colourless spray fluids. It is reasonably accurate over a large range of droplet sizes provided that the thickness of the oxide film is greater than the droplet diameter ; the effect of oxide film thickness is illustrated in Plate IX (c) and (d). The chief disadvantage of the method for use in the field lies in its sensitivity to the angle of impingement of the droplets, as described above. The ratio of impression size to drop size for aqueous sprays was found to be 1.14, a figure that agrees reasonably well with May's value of 1.16 (7).

Stains on Plaster of Paris. Plaster of Paris provides a very absorbent surface, and under most conditions circular stains are produced (Plate IX (e)). The method is ideal under field conditions since the plaster slides are easy to handle. The method is, however, satisfactory with only a limited number of sprays, since the spray fluid must be coloured or it must be possible to develop the stains after collection. As described above, not all dyestuffs are suitable for colouring the sprays, and if the stain is developed after collection, all the samples must receive identical treatment. The stain size/drop size ratio for a copper sulphate spray developed with a solution of sodium diethyldithiocarbamate was found to be 5.74.

Stains on Paper Surfaces. In order to give satisfactory stains the paper surface should be absorbent and uniform; useful stains have been obtained on several types of Whatman filter papers, including Nos. 1, 42, 50 and 120. The stains produced do not photograph very well but in all cases they are similar to those illustrated in Plate IX (f). The use of a semi-absorbent paper whose surface was not uniform is illustrated in Plate IX (g) and (h); it is clear, particularly with the higher magnification, that the stains produced are far from circular.

Under field conditions filter paper surfaces are very satisfactory, again provided that the spray is coloured or that the stains may be developed after collection. At very small drop sizes the stain size/drop size is not absolutely constant but such small drops usually represent less than 5% of the total volume of spray. The ratio of stain size/drop size for Whatman's No. 120 reaction paper was found to be 4.05 using aqueous rhodamine solution, and 7.33 using copper sulphate developed with sodium diethyldithiocarbamate. Owing to the high ratio of stain size to drop size this method is likely to be very prone to variations in surface tension, viscosity and volatility of the spray fluid.

Conclusions.

The accuracy of the various methods available for the estimation of small spray droplets depends upon the conditions under which they are used. So far, no method has been found that will give accurate results over the whole range of conditions likely to be encountered in the field. The magnesium oxide method will give good results provided that the spray droplets are not too large and the slides are placed where the spray will impinge vertically on the collecting surface. Absorbent paper or plaster of Paris surfaces are easier to use than the magnesium oxide method and will give accurate results with all but the smallest spray droplets. It is most important with all these methods that, before using them on a large scale, the stain size distribution should be checked against the drop size distribution in the particular formulation of spray to be used, after which the stain size/drop size ratio may be evaluated.

Summary.

Various methods for the estimation of small spray drops, including impressions in magnesium oxide, stains on glass, plaster of Paris and various paper surfaces are compared.

It is shown that the stain size distribution may be readily compared with the actual drop size distribution when both are plotted using the Rosin-Rammler expression.

The chief factors influencing the stain size/drop size ratio are discussed; they include the absorption of the drop by the collecting surface, the momentum of the drop as it strikes the surface and the angle of impingement of the drop on the surface. Owing to the effect of these three factors, none of the methods employed will give perfectly accurate results over the whole range of conditions likely to be encountered in practice.

The conditions under which the various stain size methods may be employed are considered: for most field work, the magnesium oxide method and the stain methods on filter paper and plaster of Paris are sufficiently accurate.

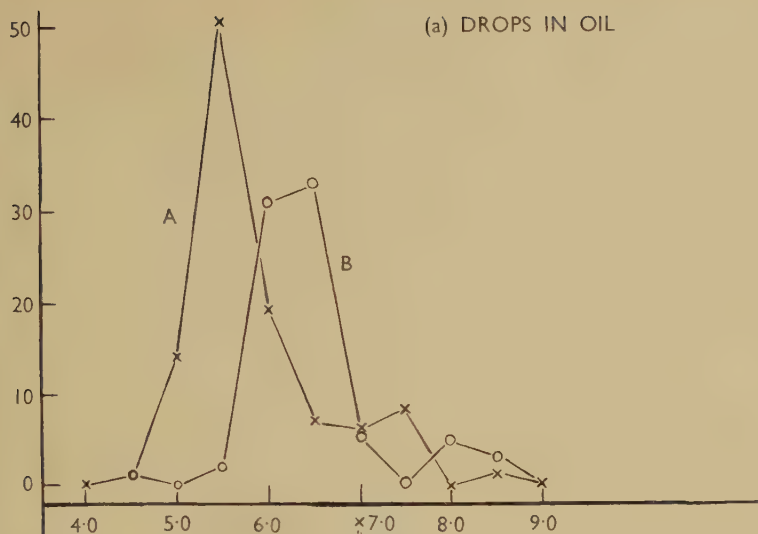
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I am indebted to Dr. H. G. H. Kearns for his suggestion and support of this work, and to Mr. N. G. Morgan and Mr. G. M. Clarke for their assistance.

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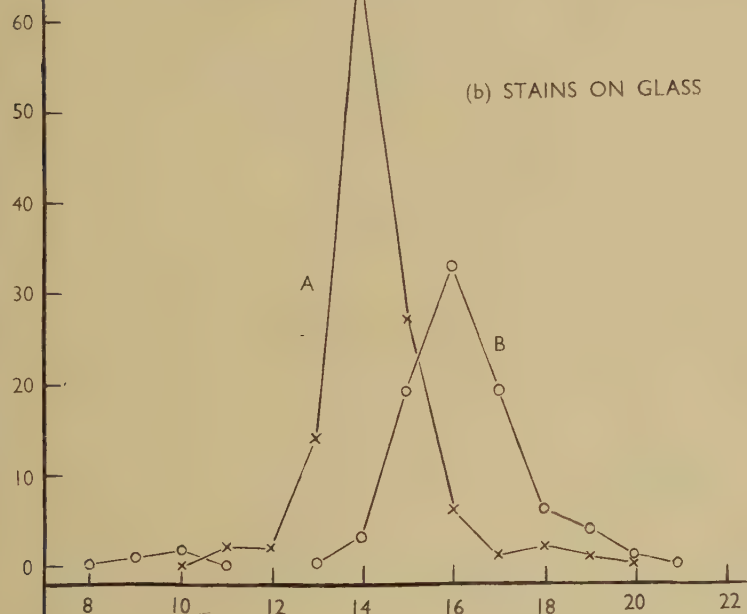
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(a) DROPS IN OIL

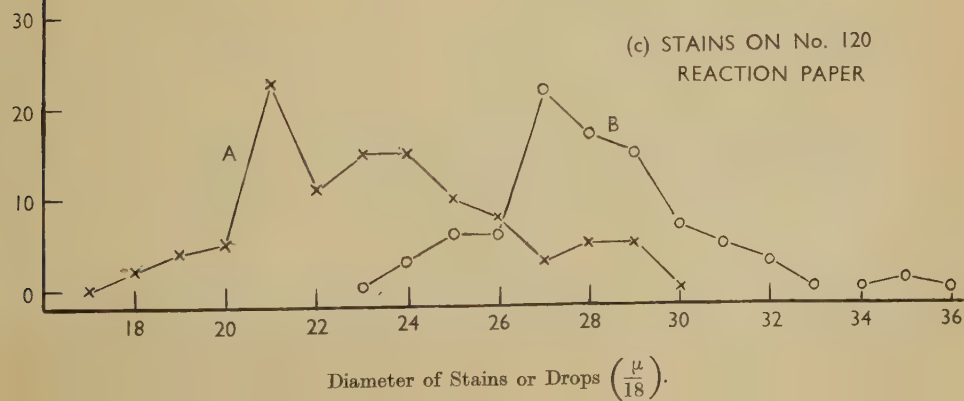


(b) STAINS ON GLASS

NUMBER OF STAINS OR DROPS



(c) STAINS ON No. 120 REACTION PAPER

Diameter of Stains or Drops ($\frac{\mu}{18}$).

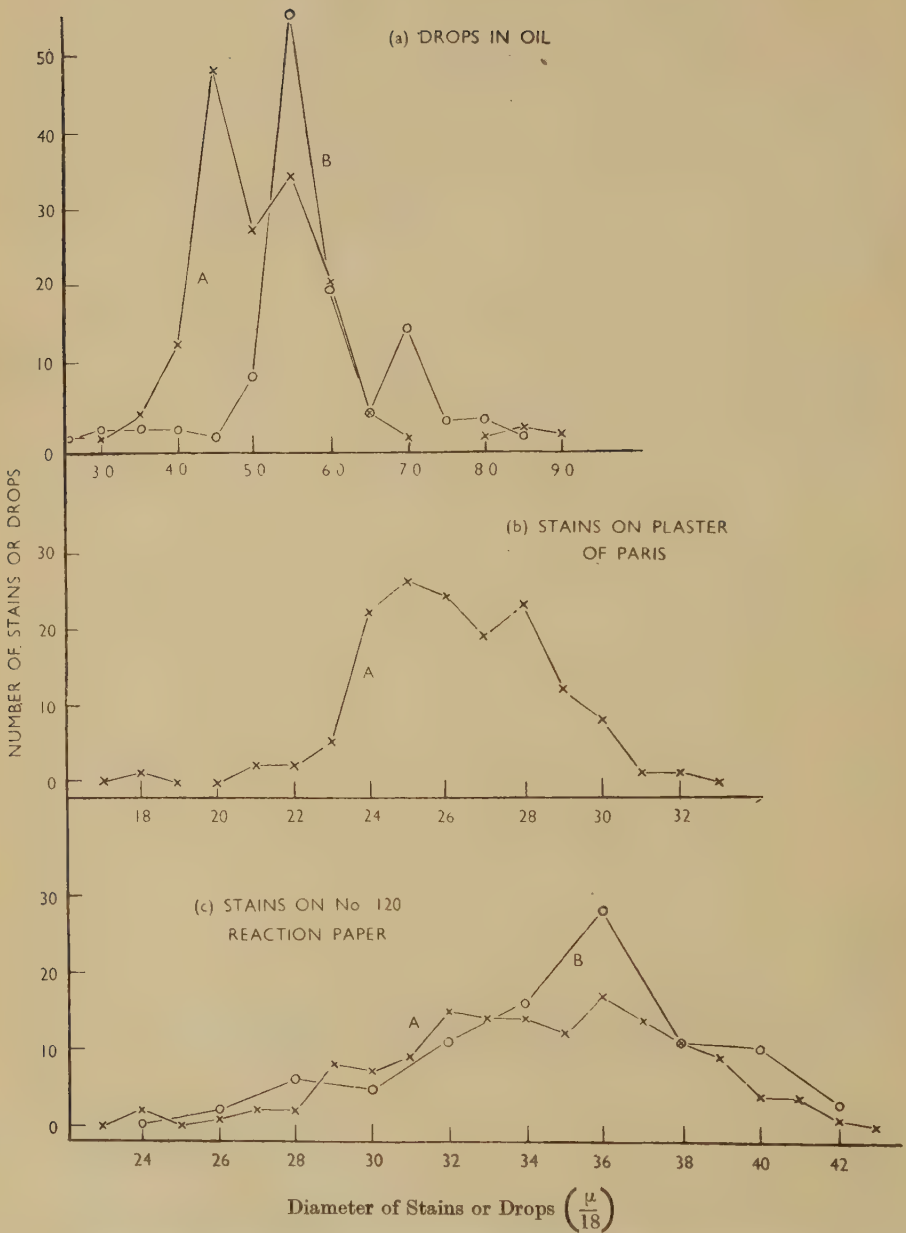


Fig. 2. Spray Frequency curves of a copper sulphate solution : stains developed with sodium diethyldithiocarbamate.

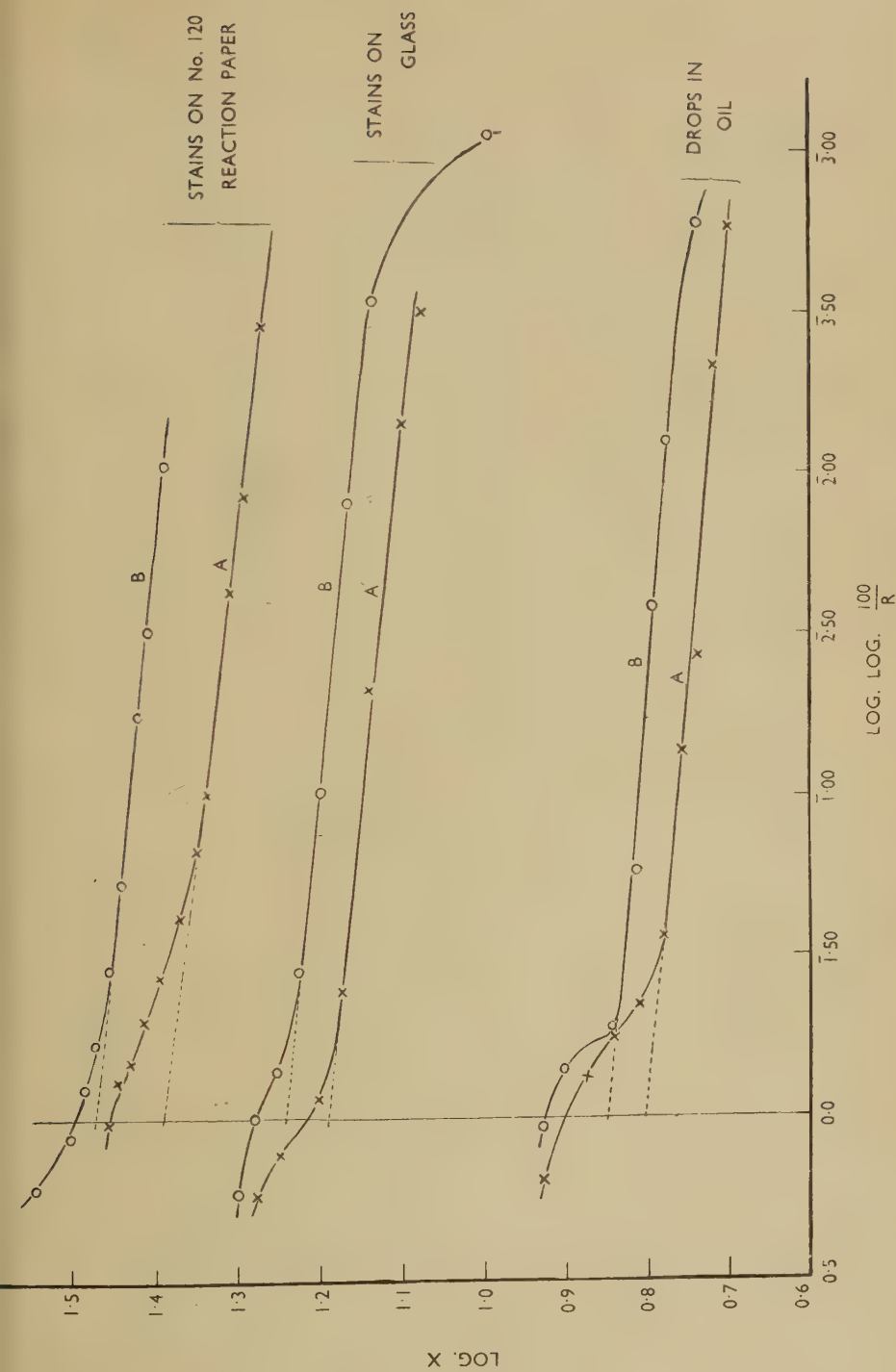


Fig. 3. Rhodamine Results (Fig. 1) plotted using the Rosin-Rammler Expression.

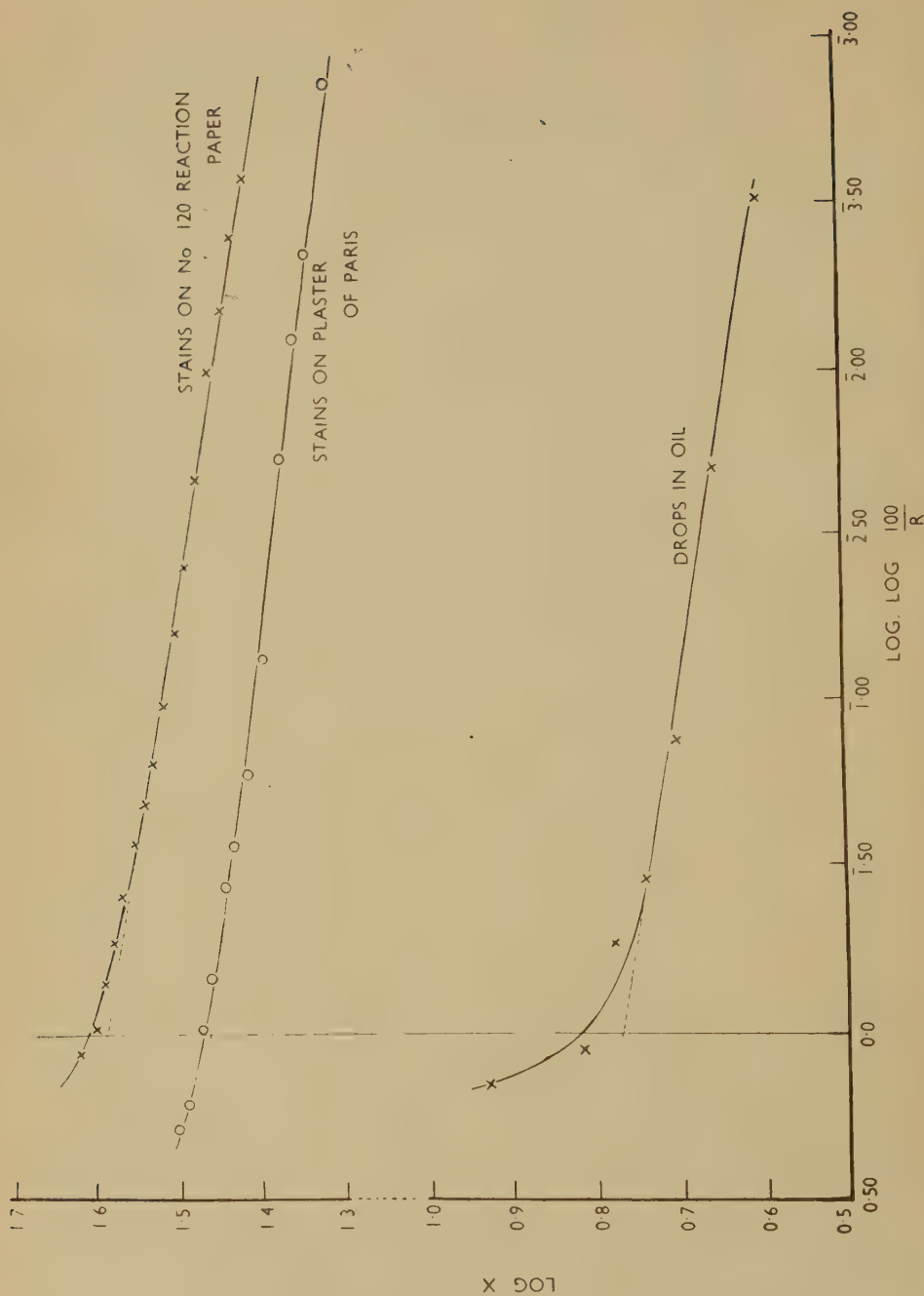


Fig. 4. Copper Sulphate Results (Fig. 2) plotted using the Rosin-Rammler Expression.

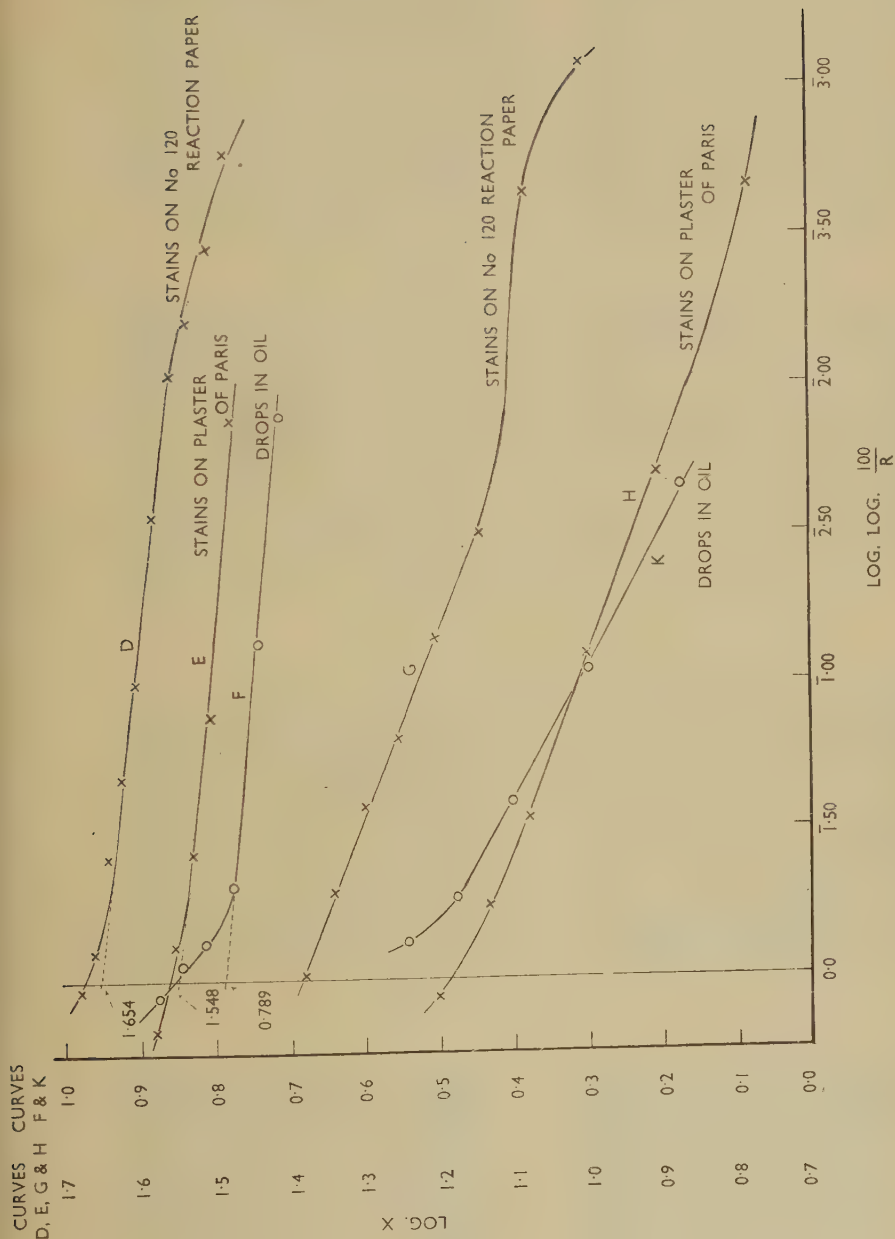


Fig. 5. The Effect of Momentum of droplets on Stain Size.

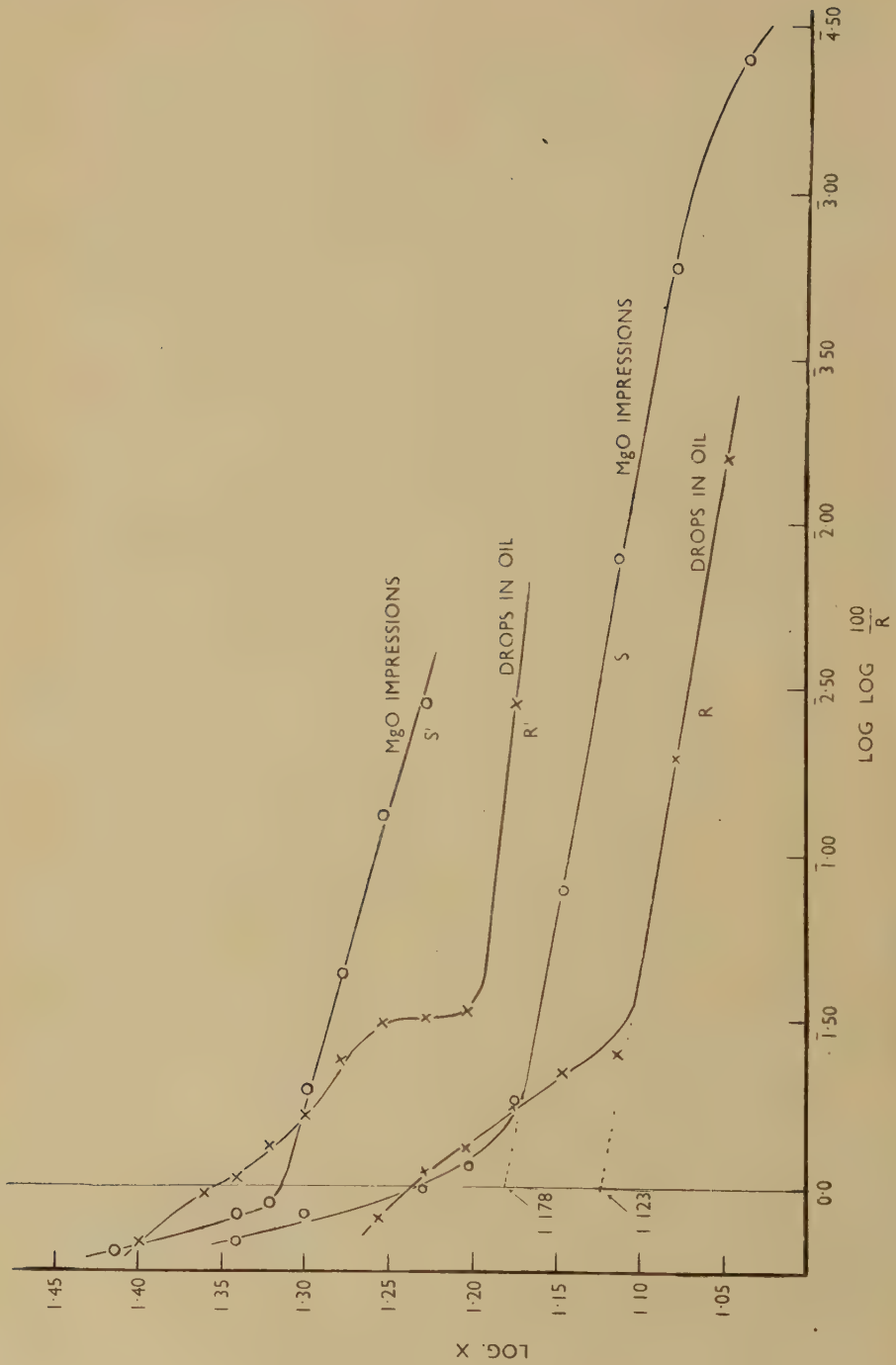
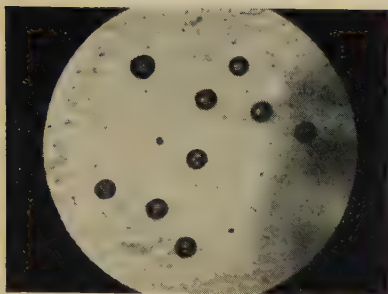
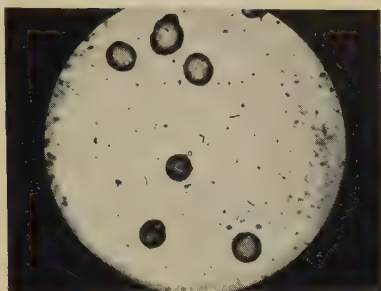


Fig. 6. The Effect of Angle of Impingement on Magnesium Oxide Impressions.

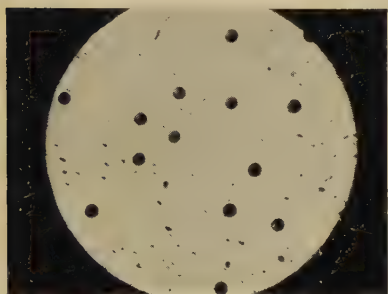
PLATE IX



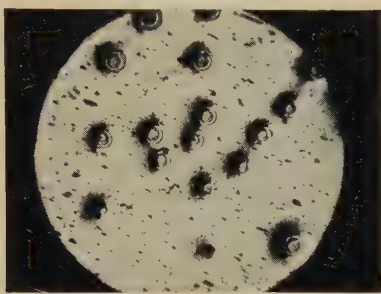
(a) Droplets in oil $\times 20$.



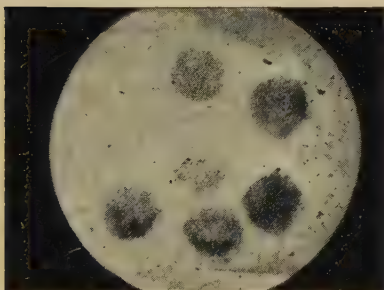
(b) Stains on glass $\times 10$.



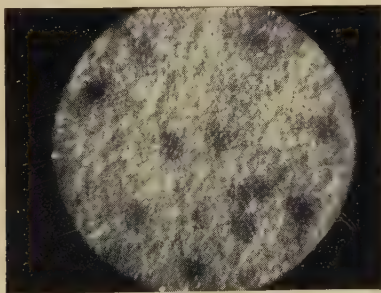
Impressions produced by $100\ \mu$ diameter drops in magnesium oxide $\times 10$.
(c) Thickness of oxide film $300\ \mu$.



(d) Thickness of oxide film $50\ \mu$.



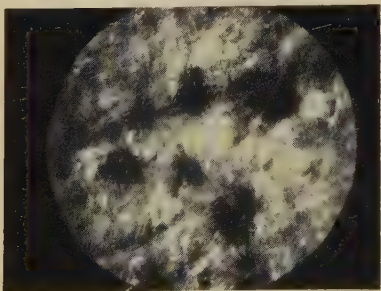
(e) Stains on Plaster of Paris $\times 10$.



(f) Stains on Whatmans No. 50 filter paper $\times 6$.



(g) $\times 10$.



(h) $\times 20$.

Stains on a semi-absorbent paper.

SPRAY APPLICATION PROBLEMS :
XVIII. OBSERVATIONS ON THE APPLICATION
OF CHLORBENSIDE FOR THE CONTROL OF THE
WINTER EGGS OF THE RED SPIDER MITE
(METATETRANYCHUS ULMI KOCH).

By H. G. H. KEARNS, N. G. MORGAN and A. H. WILKINS.

The use of post-dormant sprays of DDT and BHC, which are toxic to certain predators of the Red Spider mite, has led to increasing Red Spider infestation of apples and plums. Such infestations can now be controlled by the use of a mite ovicide such as chlorbenside (*p*-chlorbenzyl *p*-chlorphenyl sulphide) which is highly effective against Red Spider eggs.

The overwintering eggs of this mite are laid on the bark, mostly at the base of the buds. The bark and the eggs are readily wetted, and the combination of ease of wetting and exposed position of the eggs favours the efficacy of run-off washes applied not later than the pink-bud stage when there is little obstruction by foliage.

Graham *et al.* (1) reported that chlorbenside gave an outstanding control of Red Spider when applied at 0.05% concentration to apples at the green-cluster/pink-bud stage. Optimum results were obtained from an application made before the main hatch of winter eggs at the pink-bud stage in order to exert maximum ovicidal effect and at the same time ensure sufficient leaf area to retain deposits to kill mite larvae.

When the wash is applied to foliage it is able to "diffuse" from the top surface of a leaf and kill eggs on the underside. This property is of great importance, especially as the difficulty of ensuring cover on the leaf undersides increases after the pink-bud stage owing to the development of obstructing foliage.

In the present investigation, experiments were made to determine the effect on the winter eggs of the time of application of two formulations of chlorbenside at two concentrations and at four stages of apple flower bud development.

Method of Assay.

In view of the difficulties associated with field assays of acaricides, the assays were carried out under laboratory conditions that permitted accurate determination of the fate of the eggs, yet at the same time maintained the eggs in a normal environment.

Random collection of infested wood is unsatisfactory, as most of the eggs are laid on two-year-old shoots and this leads to a confusion between dead unhatched eggs of the previous season and the new viable ones. This difficulty was overcome by infesting with mites clean one-year-old shoots of apple root-stocks grown in pots during the late summer. The population of mites had to be adjusted to avoid too high a number as this would have increased the risk of producing a high percentage of non-viable winter eggs. Only a very small number of the summer eggs laid on the wood failed to hatch so no complication was introduced when counting the number of winter eggs.

The infested stools were kept out of doors exposed to the weather until required for treatment. The eggs were clustered around each vegetative bud and for treatment a number of shoots were cut into $\frac{3}{4}$ "-long pieces including a bud. For each treatment a random sample of ten pieces, each with about 500-600 eggs, was taken and dipped in the constantly-agitated emulsion taking care to avoid damaging the eggs. Each piece of wood was then placed vertically and allowed to drain and dry.

The end at which draining occurred was cut off and discarded to avoid a localised area of high concentration of acaricide and the remainder mounted vertically on a pin on a wooden batten. The treated portions were kept out of doors in a cage subjected to weathering until it was noted that the Red Spider eggs on the untreated controls were on the point of hatching. At this stage all the treated portions of the shoots were removed from the pins and placed in vertical $2\frac{1}{4}" \times \frac{3}{4}"$ glass tubes. On the inside portion of the top of each tube a $\frac{1}{2}"$ wide band of Tanglefoot banding grease was smeared and gently warmed to make a uniform layer.

The tubes were numbered and banked in rows in wooden holders so that only the top portion of the tube was exposed to light. The spiders on hatching from the eggs ultimately walked up the wall of the tube and became embedded in the grease.

Spray materials and times of treatment.

The chlorbenside was used at 0.05 and 0.02 per cent. concentrations as a proprietary dispersible powder and as a benzol mayonnaise emulsion. The emulsion consisted of 8 ounces of the ovicide dissolved in $1\frac{1}{2}$ pints of benzol and emulsified with $1\frac{1}{2}$ pints of 20 per cent. solution of sulphite lye of S.G. 1.3.

The dispersible powder and the emulsion gave equally good wetting of the bark, so no additional wetter was added to either. It should be noted that on foliage it would be necessary to add a wetter to the benzol emulsion to ensure adequate wetting.

The treatments were applied either 14 days before bud burst, at bud burst, at green cluster or at the pink bud stage, using as a guide the apple variety Worcester Pearmain.

Results.

The eggs were counted by removal from the bark with hot 10 per cent. caustic soda and washing into a filter paper. Counting was assisted by suspension in alcohol. The mites caught in the grease were also counted by mounting the tube so that it could be rotated beneath a binocular dissecting microscope.

The results of the various treatments and times of applications are shown in the following table. The figures are computed from approximately 6,000 eggs per treatment.

The egg material was exceptionally good, as shown by the uniformity of the hatching of the untreated controls, consisting of 50 tubes containing separate pieces of wood. The hatches of eggs at all the bud stages, excluding the pink bud, were so high that they were practically the same as the control and did not warrant statistical analysis. The only stage of bud development at which control of eggs occurred was at pink bud and it was then so outstandingly high and uniform that it was clear that there were not any significant differences between treatments.

TABLE I.

THE CONTROL OF THE WINTER EGGS OF *Metatetranychus ulmi* BY MEANS OF CHLORBENSIDE.
(Treatments at stages of flower bud development).

	14 days before bud burst 15/3/54	Bud burst 30/3/54	Green cluster 12/4/54	Pink bud 3/5/54
	% hatch	% hatch	% hatch	% hatch
<i>Chlorbenside formulations :</i>				
0.05 per cent. dispersible powder ..	98.9	98.9	91.8	1.03
0.02 per cent. dispersible powder ..	97.2	98.2	80.0	1.08
0.05 per cent. emulsion	98.9	84.3	98.5	1.02
0.02 per cent. emulsion	98.8	93.6	97.7	1.09
Control 1	—	—	—	98.5*
2	—	—	—	99.0
3	—	—	—	99.1
4	—	—	—	98.5
5	—	—	—	99.2

*Peak date of hatch 8/5/54.

Summary.

- (1) *p*-Chlorbenzyl *p*-chlorphenyl sulphide (chlorbenside) applied at 0.05 and 0.02 per cent. concentration either as a dispersible powder or as a benzol emulsion gave a 99 per cent. kill of the winter eggs of *Metatetranychus ulmi* when applied at the pink bud stage of the apple Worcester Pearmain.
- (2) At earlier stages of bud development the ovicide provided little or no control.

Acknowledgments.

Thanks are due to Boots Pure Drug Co. Ltd. for the supply of the chlorbenside.

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SPRAY APPLICATION PROBLEMS : XIX. FURTHER FIELD EXPERIMENTS ON THE CONTROL OF APPLE SCAB BY SMALL-VOLUME SPRAYS.

By H. G. H. KEARNS, R. W. MARSH and N. G. MORGAN.

Trials made in 1953 (2) showed that four air-flow applications of 1% lime sulphur at 100 gal. per acre were inadequate for the control of scab on bush apple trees in a wet season. In the 1954 trials the volume of lime sulphur applied was reduced to approximately 50 gal. per acre whilst the number of applications was increased and the concentrations were raised to 2% and 4%. For comparison, a normal programme of large-volume lance applications of lime sulphur was included. A similar trial was made using captan.

Experimental.

The lime sulphur trials were made on Cox and Worcester trees in Plots 14 and 15 of the Long Ashton plantations. Plot 15 is a continuation of Plot 14, which was described in the report of the 1952 trials (1). Comparisons were also made between the effects of small-volume air-flow and large-volume lance applications of captan, at 0.4% and 0.1% respectively. The captan trials were on a block of Cox trees (in Plot 23) spaced at 21 ft. diagonally. The lay-out of the two trials is shown on p. 137.

The small-volume sprays were applied by an air-flow mist blower with a fishtail fan trunking as previously described (4). The large-volume applications were made with a tractor-drawn spray pump supplying a hand-directed broom carrying three nozzles each fitted with a disc having a 5/64 in. aperture. The mean application rate for the large-volume sprays was 500 gal. per acre.

The lime sulphur employed was a standard proprietary product used at 1%, 2% or 4% by volume. Captan was used as a 50% proprietary formulation (SR 406) applied at 2 lb. per 100 gal. for the large-volume sprays and at 8 lb. per 100 gal. for the small-volume air-flow treatments. Sodium dioctyl sulpho-succinate at 0.025% was used as a wetting agent throughout the trials.

The complete spraying programme is set out in Table I. As in previous years spray drift seriously affected the control plots, particularly those on the northern side of Plot 14.

Except during May, the 1954 season was again favourable for scab at Long Ashton. Rainfall in inches was as follows : May 2.21 (2.59), June 4.22 (2.11), July 4.05 (3.16), August 3.32 (3.65), September 6.08 (3.15). (The bracketed figures show the 1914-53 means). Temperature and sunshine were markedly below normal throughout the summer.

Results.

In Plots 14 and 15 mean percentage scabbed area per fruit and percentage number of fruits badly russeted were recorded on 12th September for four Cox trees in each of the treatment blocks A, B, C, D, E, F and G. Recordings of mean percentage scabbed area of leaves and fruit of Worcesters were made

on 28th–31st July using the following numbers of trees per treatment : A, 5 ; B, 7 ; C, 8 ; D, 10 ; E, 5 ; F, 3 ; G, 9. For each tree of Worcester or Cox samples of 250 leaves or 100 fruits were assessed as previously described (5).

In Plot 23, and also in Plots 14 and 15, percentage weights of scabbed fruit harvested from the Cox trees were recorded.

The results obtained are assembled in Table I where the values represent the overall means per treatment.

In both trials the superior scab control resulting from the large-volume lance spraying is obvious. Also, in trial I, a significant difference in scab control was shown between Treatments B and C and between D and E. This indicates that where application 5 was omitted, leaving an interval of 25 days between 11th June and 7th July, the deposits from the small-volume 1% and 2% lime sulphur were insufficient to maintain scab control. In Treatments A and F, however, the deposits were apparently sufficient to bridge the 25-day gap.

In trial II a similar interval occurred between applications 7 and 8 (13th May to 3rd June). Here again, small-volume air-flow applications of “normal” concentration captan failed to control scab, while similar applications of captan at four times normal concentration gave appreciable control, and large-volume applications at normal concentration gave virtually complete control.

None of the air-flow applications of lime sulphur caused a percentage of russetting significantly higher than in the unsprayed blocks, but the large-volume lance applications caused extensive russetting which rendered valueless about half the Cox crop.

Summary.

Field trials on methods of application of lime sulphur and captan for apple scab control are described. Results showed that large-volume run-off spraying with either material at “normal” concentrations gave virtually complete control, but lime sulphur applied in this way caused extensive russetting on Cox.

Scab control was unsatisfactory after five small-volume air-flow applications at 50 gal. per acre using 1 or 2% lime sulphur or 0.1% captan, but an increase in either the number of applications or to a fungicide concentration of four times “normal” gave a high degree of control.

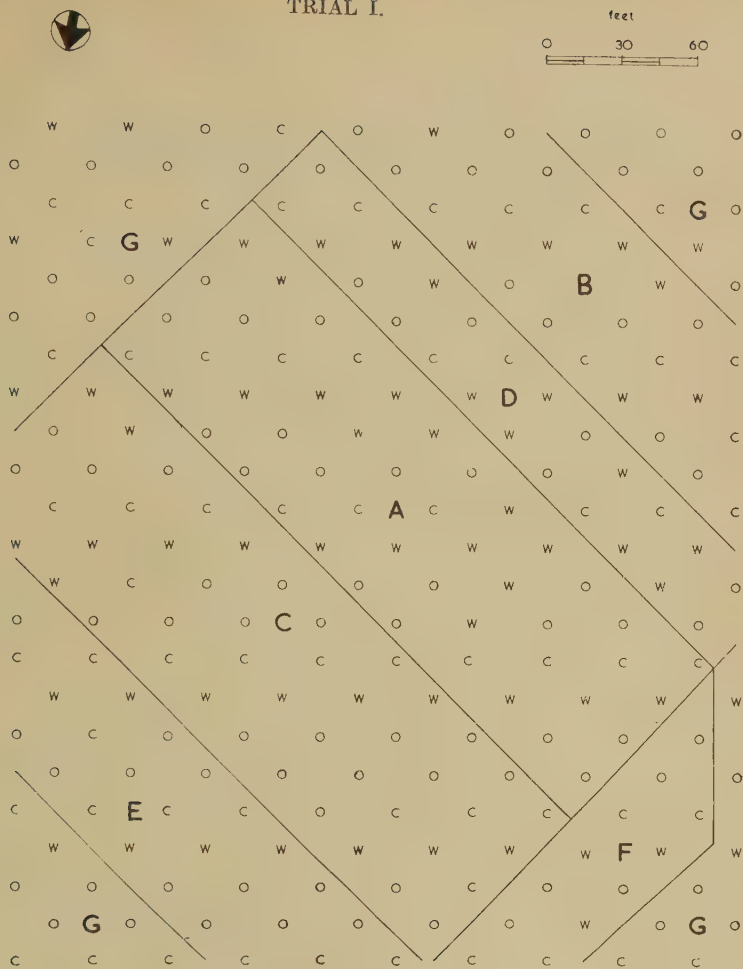
Acknowledgments.

Thanks are due to Messrs. C. H. Harper and J. H. Russell for assistance with spraying and fruit counts and to Miss S. Freezer and Mr. P. D. Turner for help in recording.

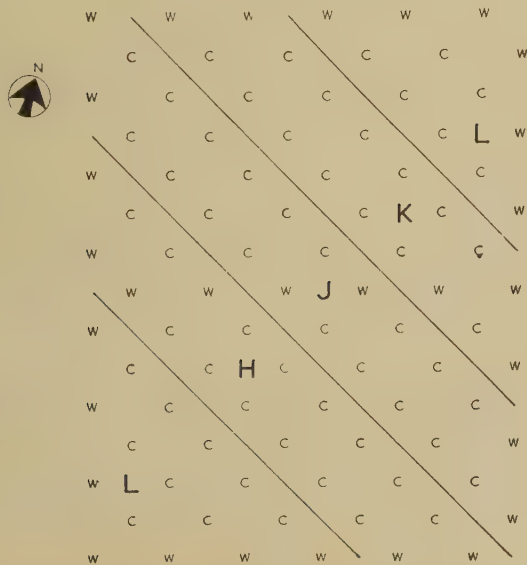
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TRIAL I.



TRIAL II.



SPRAY APPLICATION PROBLEMS :

XX. LIGHT-WEIGHT SMALL POWER SPRAYERS (34 and 70 c.c. I.C. engines).

By H. G. H. KEARNS and N. G. MORGAN.

The ever-increasing use of highly effective fungicides and synthetic insecticides has stimulated a demand, particularly in the Colonial Territories, for efficient and simple small power spraying machinery. The equipment is required for a wide range of duties ranging from the application of malaricides to the spraying of bananas on steep hill slopes. The commercially available power equipment generally comprises a small 4-stroke engine and reciprocating pumps operating up to about 300 lb. p.s.i. mounted on a carrying chassis. Some of the smallest of these machines are 100 lb. in weight and many weigh considerably more. Machines of this weight are difficult to transport by hand on rough ground and even more so up steep hill slopes. This excessive weight encourages the procedure of parking the outfit in a convenient position and pumping the spray fluid long distances through hoses. Very often this results in considerable losses of pressure and therefore wasteful use of horse power. A survey of the performance of many small outfits on tropical crops showed that very often the delivery of the pump was 2-4 gallons per minute at 300 lb. p.s.i., whereas only $\frac{1}{2}$ to 1 g.p.m. throughput was required at the nozzle: this represented a wasted pump capacity both in volume and flow pressure. With these small throughputs little is gained by using a flow pressure greater than 75 lb. p.s.i. as suitably designed nozzles will give as satisfactory spray patterns as a nozzle operating at 300 lb. p.s.i. Small throughputs of the order of 0.5-1.0 g.p.m. cannot give long distance carry from the nozzle, so a lance of a length to suit the particular crop must be used. Thus on pine-apples a 3 ft. lance is adequate whereas on bananas a 10 ft. lance may be necessary to ensure effective coverage of the target.

The existing power outfits often comprise a 4-stroke I.C. engine of about 100-150 c.c. capacity with a small sump for the oil, which often falls to a dangerously low level once appreciable cylinder wear has occurred. If the engines are ill used, burning of the exhaust valve is frequent and is accompanied by rapid fall off in performance.

Small reciprocating plunger pumps, generally with two plungers, are used. The better designs have stainless steel or ceramic coated plunger barrels in which synthetic bucket plungers operate. These pumps, unless of very small bore and stroke of the order of $\frac{3}{4}$ " $\times$ $\frac{3}{4}$ ", operate at relatively low speeds and therefore it is necessary to include a countershaft in the design in order to obtain a ratio of engine to pump speed of the order of 2,000 to 150 r.p.m. The pump also requires efficient suction and delivery valves for each plunger. The design is therefore fairly complicated and requires regular maintenance, especially of lubrication of the journals of the plungers and countershaft. The valve gear is also subject to fairly rapid abrasion and corrosion which causes a decrease in efficiency.

The complexities of maintenance and weight of the above type of outfit showed a need for a much lighter, cheaper and simpler machine. The machine

should be preferably of such design that by the time it requires an overhaul it has paid for itself many times over in efficient work. It is also desirable, especially if it is to be used by native labour, that lubrication and maintenance shall be reduced to the minimum so as to avoid constant interruptions in spraying.

The small 2-stroke internal combustion engine scores over the 4-stroke in simplicity of design, considerable reduction in weight and a simple and reliable form of petrol/oil lubrication. In the past it has earned a bad name as a bad starter but modern designs have overcome this earlier fault. It can be relied upon to give 800 hours of service before a major overhaul is necessary, incurring a repair charge of about £5.

Alternatives to the reciprocating plunger pump are the gear and centrifugal types, both able to operate with very little attention at 75 lb. p.s.i. The small gear pump is extensively used on row-crop sprayers for the application of plant protection materials, as its small size, simplicity of design, easy maintenance and low price more than compensate for its relatively shorter life.

Small outfits using the two above components have been designed so that they can be readily carried and therefore be suitable for a wide range of duties requiring small throughputs.

Specification.

The equipment consists of three major components, a tubular frame, a 2-stroke engine and a gear pump. Two sizes of outfit have been designed each using the same sized tubular frame. One consists of a 34 c.c. engine and a $\frac{3}{8}$ " B.S.P. gear pump and weighs 33 lb. : the second and larger outfit with a 70-80 c.c. engine and a $\frac{1}{2}$ " B.S.P. gear pump weighs 55 lb. approx. The general assembly of the machines is shown in Plates Nos. X and XI.

The frame. The frame is of bent tubular design, using $\frac{3}{4}$ " O.D. $\times$ 18 G. drawn steel tube and fabricated by brazing or electric arc welding. The main items are a basal oval ring to which two pairs of vertical supports are fitted with cross tubular members. The larger engine is mounted on two vertical strip iron supports and the smaller engine on a $\frac{1}{8}$ " plate. The pump in both models is mounted on an inclined plate which is slotted in the centre to allow movement of the pump for adjustment of belt tension.

On the base of the frame provision is made for screwing in four long pegs which keep the outfit stationary on soil. These steel pegs are replaced by rubber pads when the outfits are used on smooth surfaces such as wood floors, concrete, etc., in buildings. The assembly of all the components into the frame is extremely simple and can be completed within 15 minutes, as it comprises the use of six bolts in the 34 c.c. machine and eleven bolts in the larger model.

The machines are robust and can easily be carried by two operators and fairly easily by one, more particularly the 34 c.c. machine.

The engines.

On the larger machine either a 70 c.c. Villiers or an 80 c.c. J.A.P. (Type 2) 2-stroke engine can be fitted with the cylinder horizontal, with minor adjustments of the frame and by fitting a manifold to suit the siting of the carburetter.

The smaller engine, a 34 c.c. J.A.P. model O, is fitted, with the cylinder vertical, to a plate welded across the frame width, the drive shaft protruding

through a circular aperture. The engines are fitted with an impeller fan flywheel and cowling for adequate cooling.

The carburetter is controlled by means of Bowden cable with the lever sited in a convenient position on the frame. The petrol tank is cylindrical with a working capacity of 4 pints and bolted by substantial brackets to the frame. A "push and pull" on-and-off cork-faced petrol tap is joined by a flexible petrol-proof tube to the carburetter.

The spark plugs are of the detachable central electrode type for easy cleaning under field conditions and the terminal is fitted with a moisture protection cap to prevent engine cut-out by shorting from spray drift and rain. The Lodge 14 and K.L.G. F50 14 mm. spark plugs are suitable types.

The larger engine (70-80 c.c.) develops 0.75 h.p. approx. at 2,000 r.p.m. and the smaller (34 c.c.) 0.3 h.p. approx. at 2,500 r.p.m. The performances are reduced at the rate of 1 per cent. for each 10°F. rise in temperature above 60°F. and about 3 per cent. for each 1,000 ft. rise in elevation above sea level.

The pump.

The 70-80 c.c. engines are able to drive with an adequate reserve of power a pump with a delivery of 2 gallons of water per minute and the 34 c.c. will deliver 8 pints per minute at a flow pressure of 75 lb. p.s.i. The performance will vary with the design of pump. Gear pumps have been selected for the machines on account of their simplicity, compactness, light weight and low cost. They will give good service in relation to their cost and ease of maintenance provided that they are protected from undue abrasive wear. The pump body and gears and shaft should be made of corrosion- and abrasion-resistant materials; phosphor bronze has proved excellent for the body and gears and a stainless steel for the shaft. The efficiency of the pump depends largely on the correct maintenance of the small clearances between the gear teeth and the wall of the casing and between the sides of the gears and the side plates of the pump.

Any undue wear of the bearings or shafts of the gears leads to rapid wear of the casing and side plates. Shaft bearing wear is frequently overlooked and in some designs inadequate attention is given to the design of the bearings. The most popular design consists of accurately bored holes in bosses on the end plates. This method is satisfactory provided lubrication can be maintained, and no trouble arises if the pump is used for pumping clean oils. However, most spray materials used in agriculture are water-borne and contain emulsifiers or detergents: the latter very quickly remove the greases used on the bearings even if selected for their resistance to emulsification. It must therefore be assumed, more especially with native labour in the tropics, that greasing will generally be done sporadically and the bearings often run without lubrication apart from that provided by the spray liquid passing through the pump. It is therefore preferable to fit bearings that are designed for both grease and water lubrication, but it is still advisable to fit a grease cap as it is desirable though not essential to leave the bearing and shaft coated with a water- and detergent-resistant grease during periods of disuse. There are several plastic materials or plastic-bonded materials that are suitable as bearings. It is an advantage if the idler gear is bushed with the plastic bearing as well as having its shaft running in plastic bearings, thereby distributing the wear over a wider surface.

The drive shaft is fitted with a stuffing gland which can be adjusted by a gland nut. The packing is generally braided hemp cord impregnated with tallow and colloidal graphite. This forms an efficient seal so long as the packing remains supple, but some spray fluids, for example, lime sulphur and Bordeaux mixture, cause fairly rapid hardening of the packing. This may cause a scoring of the shaft if the gland is tightened up too much. The packing gland when in good condition should be just more than finger tight. In some designs of pumps a replaceable spring-loaded synthetic rubber or plastic seal is fitted. This type of seal only remains efficient provided the surface of the shaft is perfectly smooth.

A pressure-relief valve is incorporated in the casting of the pump body, so that surplus or total capacity can be returned to the suction inlet. The best design for spray fluids is a phosphor bronze ball held on its seat by a monel metal, stainless steel or copper coil spring, the tension of which can be adjusted to allow of release at a pre-selected pressure. An alternative design is a relief valve that discharges the released fluid back to the tank by means of a hose: this design has the disadvantage of additional weight and another hose, but it provides a quick means of ascertaining the performance and surplus capacity of the pump.

The 70-80 c.c. machines are fitted with gear pumps described as $\frac{1}{2}$ " B.S.P. size which refers to the dimensions of the inlet and output ports. As an example a gear pump with one pair of similar gears $1\frac{1}{4}$ " diameter across the teeth and 2" long should deliver a total of approximately 2 gallons at a flow pressure of 75 lb. p.s.i. at 750 r.p.m.

The 34 c.c. machines are fitted with a $\frac{3}{8}$ " B.S.P. gear pump which should deliver one gallon at a flow pressure of 75 lb. p.s.i. at 750 r.p.m. A typical pump of this size would have a pair of similar gears 1" overall by $1\frac{1}{2}$ " long.

The size of the gears will vary with the design: if the gears are larger than the above dimensions, the speed must be reduced to suit the available horse power. Slow speeds may increase the life but increase the weight of the pump.

Smaller pumps than the above, such as the $\frac{1}{4}$ " B.S.P., cannot be relied upon to deliver at more than 50 lb. p.s.i. unless particular care has been made to obtain the minimum clearances. Higher pressure than 50 lb. p.s.i. can be obtained by increasing the speed of the pump but this may be accompanied with loss of reliability.

The pump drive.

The 70-80 c.c. engine should operate at 2,500 r.p.m. and the 34 c.c. at 2,800 r.p.m. with the pumps at 750 r.p.m.

A convenient, cheap and reliable drive is a single $\frac{1}{2}$ " diameter vee belt using aluminium vee pulleys. The 70-80 c.c. engine should be fitted with a $2\frac{1}{2}$ " engine pulley and the pump with a 8" pulley; the 34 c.c. with 2" and 8" or $2\frac{1}{2}$ " and 10" pulleys.

The pulleys should be held by a parallel key and an Allen set screw to the parallel shafts or, in the case of the taper shafts on the 70 c.c. Villiers engine, by a key and lock nut.

Endless vee belts are satisfactory, 36" long for the 70-80 c.c. engine and 34" long for the 34 c.c. with the smaller pair of pulleys. The belt tension is

adjusted by moving the pump higher on the inclined base plate and bolting down at a suitable position.

The pulleys on the engine and pump must be correctly aligned to avoid undue belt wear.

Pump fittings—delivery and suction.

The delivery port of the pump is fitted with a $\frac{3}{8}$ " or $\frac{1}{2}$ " B.S.P.M. $\times \frac{3}{4}$ " B.S.P.M. (or 1" W.M. or $\frac{3}{4}$ " American Hose thread (11½ t.p.i.)) hexagonal nipple $\frac{5}{8}$ " W. according to the locality of use. The $\frac{3}{4}$ " B.S.P.M. thread dimension is widely used in many Colonial Territories except the West Indies where the American size is commonly used. The 1" W.M. size has the advantage of withstanding rough usage and hose couplings may be tightened up on it without the use of spanners. It is not, however, widely used outside the United Kingdom. The hose coupling thread should be a free fit and the hexagonal nipple should be screwed into the pump securely.

The suction assembly for the pump consists of a hose tail-piece screwed into the pump, a suction hose and a suction filter unit. 12 feet of suction hose is a convenient length, as it allows the pump to be sited at reasonable distance from a barrel of spray. The $\frac{1}{2}$ " pump requires $\frac{1}{2}$ " and the $\frac{3}{8}$ " pump $\frac{3}{8}$ " bore hose. One end of the hose is fitted to the hose-tail of the pump by means of a worm thread clip, and the other end is fitted with a $\frac{1}{2}$ " B.S.P. lug cap and hose lining and secured by a clip. The latter assembly screws on to a filter unit. The filter unit is a most important ancillary component as it prevents the entry of all but very small particles of abrasive material into the pump. It consists of a robust body of copper tube 6½" long $\frac{3}{4}$ " bore $\times$ 19 G. walls with one end fitted with a $\frac{1}{2}$ " B.S.P.M. adaptor bored $\frac{9}{16}$ " and with the other open and with four $\frac{1}{2}$ " diameter holes in the walls. The filter element consists of a $\frac{3}{8}$ " $\times$ 18 G. brass tube with four $\frac{1}{8}$ " $\times$ 2" slots cut into the walls. On the wall three spacers are soldered so that a cylinder of 40-mesh monel metal gauze with one end closed can be fitted over it. This arrangement provides a gap of $\frac{1}{16}$ " between the gauze and tube so that the full filtering area of the gauze is effective. One end of the filter unit has a $\frac{3}{4}$ " wide ledge so that when the filter element is inserted into the body it rests on the $\frac{1}{2}$ " B.S.P.M. adaptor and is held in position by the lug nut of the suction hose. The gauze cylinder is soldered at one end to the tube and therefore can be readily replaced.

Performance.

An average performance of the two pumps is as follows :—

- (a) 34 c.c. engine $\frac{3}{8}$ " spur gear pump with gears 1" O.D. and 1½" long, 12 tooth, working depth $\frac{5}{32}$ ", tooth thickness $\frac{1}{8}$ ", pump speed 700-750.

Throughput pressure.

<i>in lb. p.s.i.</i>		<i>Total delivery in pints per minute.</i>	
free flow		11½	
25		10	
50		9¼	
75		7¾	
100		5½	
125		3¾	
150		overloaded engine.	

- (b) 70 c.c. engine $\frac{1}{8}$ " spur gear pump with gears $1\frac{1}{4}$ " O.D. and 2" long. 13 tooth, working depth $\frac{5}{32}$ ", tooth thickness $\frac{1}{8}$ ", pump speed 750-775.

<i>Throughput pressure,</i>		<i>Total delivery in pints per minute.</i>		
<i>in lb. p.s.i.</i>				
free flow	..	..	..	24
25	..	..	..	21
50	..	..	..	19
75	..	..	..	19
100	..	..	..	16
125	..	..	..	15
150	..	..	..	14
175	..	..	overloaded engine	

The effective working life of the pump varies considerably with the amount of abrasive matter in the spray fluid. Devastating wear in a very short period is caused by using Bordeaux prepared from hydrated limes containing minute particles of hard impurities. The use of water containing minute particles of sand in suspension is also an unsuspected source of rapid abrasion. Solutions, emulsions and most well-formulated suspensions of insecticides, fungicides and herbicides used at normal strengths cause only slow wear, far less wear than that caused by faulty lubrication of the shaft bearings.

A pump should give satisfactory service for 400 hours of operation.

Operation.

The lance and nozzle equipment should be chosen to suit the particular target to be sprayed. The throughput of the nozzle should be selected so that it is of the order of 75 per cent. of the figure quoted in the above tables of performances. The relief valve should be set so that the pressure is maintained on flow. Nozzles of the swirl-plate type operate best from 75 lb. p.s.i. upwards, whereas single hole flat.(fan) spray nozzles operate from as low as 10 lb. p.s.i. with an optimum at 30 lb. p.s.i. Any increase in pressure results in greater throughput without any material change in droplet spectrum.

The choice of bore and diameter of delivery hose depends on the nozzle throughput required. With an outfit of this type a $\frac{1}{4}$ " bore high-pressure hose is more convenient to use and up to 60 ft. can be used without undue loss of pressure. If longer lengths are required it is preferable to use $\frac{3}{8}$ " bore hose if the throughput exceeds 8 pints per minute. For some purposes, such as the application of malaricides, when small throughputs are used, two or more spraymen can be supplied from one pump provided the total output is within the working capacity of the pump.

Before using the machine the lubrication should be checked. The petrol should be mixed with a high-grade engine oil of S.A.E.30 at the rate of $\frac{1}{2}$ -pint to each gallon of petrol. The oil and petrol must be thoroughly pre-mixed : this is important as some types of oil do not at once disperse in the petrol.

Although it is not essential with plastic bearings, it is a good practice to screw down the grease cups on the pump before starting.

After priming the carburetter, setting the throttle control and closing the strangler, a cold 2-stroke engine should start after 3 or 4 vigorous pulls of the starting rope. If it does not start on the 6th pull it is wise to remove the spark plug and clean the electrodes. A 2-stroke engine flooded with petrol by

repeated pullings will not start until the petrol has evaporated. On no account should the carburetter of a hot engine be flooded or strangled.

Every engine has its own starting characteristics which can be found only by experience. Pump pressure should be released before attempting to start up. Once the engine has fired, the strangler is moved to the open position and the carburetter control set so that the engine runs at about three-quarters-full throttle.

On completion of the spraying it is most important to pump clean water through the outfit hoses and lances. The petrol is then turned off and the engine allowed to run until it has used up the fuel in the carburetter float chamber. Before the pump is put away into store the grease cups should be screwed down to force grease into the bearings.

Maintenance.

(a) *The engine.*

The manufacturer's instructions should be studied. The faults most likely to be met are as follows :—

- (1) After a new engine has run for a short period the contact-breaker points may require adjustment and cleaning to obtain a satisfactory spark on the sparking plug.
- (2) A blocked petrol filter gauze fitted in the body of the tap or banjo joint on the carburetter. The petrol tank should be filled through a funnel fitted with petrol filter gauze.
- (3) Air leaks into the crank case can be an unsuspected source of difficult starting or even failure to start. The bolts or bolt attaching the carburetter, the cylinder base nuts, the crank-case drain plug and the crank-case nuts must be kept tight.
- (4) The spark plug should be cleaned if any difficulty is met in starting the engine. The plug should be taken apart and the carbon and oil removed from the inside of the plug. A spare clean spark plug is advisable.
- (5) A common cause of loss of power and hot running is a deposit of carbon on the exhaust port of the cylinder, more especially in the 34 c.c. engine. This may be removed, say every 80 hours, by detaching the exhaust and carefully scraping away the carbon. The exit holes in the exhaust box must be kept clear.
- (6) Decarbonisation is rarely necessary until after 200–300 hours of running. Carbon formation in the exhaust port is a much more likely cause of loss of power (see 5).
- (7) The air cleaner or gauze, especially in dusty conditions, requires regular cleaning, and if this is not carried out an over-rich mixture from the carburetter will cause difficult starting. The cleaner should be removed, washed in petrol, allowed to drain and, if a steel wool filter, dipped into a mixture of one part petrol and two parts engine oil, then refitted after draining.

The time for a major overhaul under normal working conditions is after about 600–800 hours of running or as soon as the compression shows obvious signs of loss. This may in many cases be rectified by fitting oversize rings, or it may be necessary to re-bore and fit an oversize piston.

Occasionally an overlooked source of loss of compression and entry of air

is the failure of one or both oil seals fitted to the crankshaft. This may result from wear in a bearing which is readily diagnosed by "up and down" movement of the crankshaft.

The good performance of a 2-stroke depends very largely on the maintenance of compression, and the major causes of the loss are overheating, faulty lubrication and above all dirty air. If the engine is used under dusty conditions it is essential to fit a larger type of oil type air cleaner.

(b) *The gear pump.*

Some points of maintenance have already been mentioned in the description of the pump. The important features are as follows :—

- (1) The relief valve on the pump is adjusted to deliver the required throughput at a flow pressure not exceeding 75 lb. p.s.i. This is best carried out by fitting a reliable pressure gauge to a "tee" hose-to-lance test gauge assembly at the base of the lance fitted to say 30 ft. of $\frac{1}{4}$ " bore hose. A disc of the required throughput at 75 lb. p.s.i. is fitted to the nozzle and the relief valve is then adjusted during the spraying until 75 lb. p.s.i. is registered.
- (2) Use a detergent- and water-resistant grease and on no account a hard grease in the screw-down grease cups. Take care when fitting the grease cups to avoid the inclusion of any dirt. Screw down the grease cups before and after completion of the spraying. Over-greasing is preferable to under-greasing.
- (3) Clean the filter element frequently.
- (4) Pump through a pail of clean water on the completion of spraying.
- (5) Tighten the nut of the stuffing-gland box on the pump drive shaft when it commences to leak. If the gland requires considerable tightening to prevent leakage it is necessary to repack it.
- (6) If the pump performance decreases, check that the belt drive is not slipping, and if it requires adjustment avoid too tight a belt as this will result in undue wear of the pump bearings.
- (7) If the pump fails to function it is often due to a blocked filter or an air leak into the suction hose above the water level. When a pump has not been used for a long period and it fails to prime itself the fault may be rectified by removing the filter element and filling up the suction hose with spray and allowing it to run into the pump, then refitting the filter element and replacing it in the spray fluid. A persistent failure may be due to an air leak through the stuffing box.
- (8) The ball of the relief valve occasionally sticks, especially after a long period of disuse, and if the tap on the lance is closed the abnormally high pressure will stop the engine. The fault is readily rectified by unscrewing the valve assembly, dislodging the ball from its seat and then reassembling and re-setting the adjustment to its original position. This may be done by noting the number of exposed threads on the adjustment or by re-setting with a pressure gauge.
- (9) When, despite all adjustments, the pump throughput falls considerably below the figures given in the paragraph on performance it indicates that it requires an overhaul which can only be carried out with specialised equipment and knowledge.

Summary.

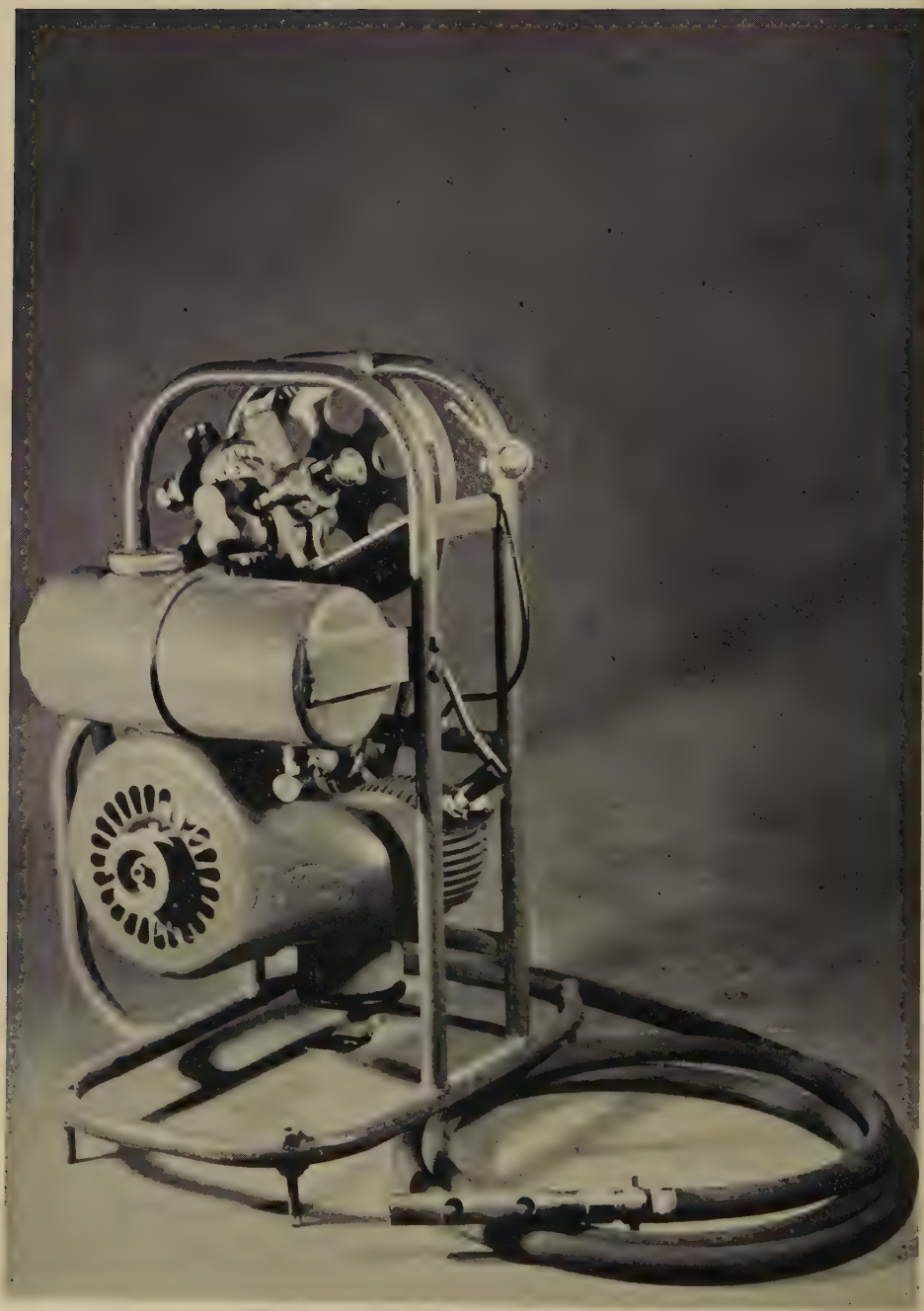
- (1) Specifications of two small simple light-weight spray machines are given. One machine is fitted with a 34 c.c. 2-stroke engine and a $\frac{3}{8}$ " B.S.P. gear pump and weighs complete 33 lb., and a larger machine with a 70-80 c.c. 2-stroke engine and $\frac{1}{2}$ " B.S.P. gear pump weighs 55 lb.
- (2) The 34 c.c. machine has a throughput of approximately 8 pints per minute at 75 lb. p.s.i. and the 70-80 c.c. machine 19 pints per minute at 75 lb. p.s.i.
- (3) These spray machines can be carried and are primarily designed for a wide range of duties by native labour in the Colonial Territories.
- (4) The design aims at simplicity of operation and maintenance. The engine depends on petrol/oil lubrication and the pumps are fitted with plastic bearings suitable for water lubrication.

PLATE X



SMALL POWER SPRAYER.
Tubular frame of the 70 c.c. machine.

PLATE XI



SMALL POWER SPRAYER.

General assembly of the machine with a 70 c.c. engine, $\frac{1}{2}$ " B.S.P. gear pump, suction hose and filter.

SPRAYING EXPERIMENTS AGAINST APPLE SCAB AT LONG ASHTON, 1954.

By R. J. W. BYRDE, G. M. CLARKE and C. W. HARPER.

Trials of fungicides at Long Ashton and East Malling from 1950 to 1953 demonstrated the value of captan for the control of apple scab, caused by *Venturia inaequalis* (Cooke) Wint. (1-5). Its fungicidal performance against the disease was at least the equal of lime sulphur, whilst increased crops of Cox's Orange Pippin were recorded as a result of the elimination of sulphur injury to which this variety is prone. There was evidence, however, that captan was not effective in controlling apple mildew, caused by *Podosphaera leucotricha* (Ell. and Everh.) Salm.

In view of the widespread interest in captan, a large-scale trial on Cox's Orange Pippin was set out in 1954, to compare a spray programme in which it was substituted for lime sulphur in the post-blossom applications, with one in which lime sulphur was used throughout. It is proposed to continue the trial during 1955 and 1956 with a view to determining the long-term effects of the treatments on crop, disease incidence and spray damage.

Experimental.

Fungicides. The spray materials were formulated as follows :—

Lime sulphur, as the commercial concentrate, diluted to 2%, 1% or $\frac{3}{4}$ %.

Captan (N-trichloromethylthio-tetrahydrophthalimide) as an aqueous suspension of a commercial wettable powder (50% captan), used at $1\frac{1}{2}$ lb. per 100 gal.

TABLE I.
SPRAY APPLICATIONS DURING 1954: QUANTITIES PER 100 GAL. WASH.

Date	Stage	Fungicide	Insecticide, Acaricide etc.	Wetter
April 12	Early green-cluster	Lime sulphur 2 gal.	DDT (a) 4 oz. Gamma BHC (a) $1\frac{1}{8}$ oz.	Dioctyl sodium sulpho-succinate (b) 4 oz.
May 7	Late pink-bud	Lime sulphur 1 gal.	—	—
May 18	Petal fall	(i) Lime sulphur $\frac{3}{4}$ gal. or (ii) Captan (50%) $1\frac{1}{2}$ lb.	Gamma BHC (a) $2\frac{1}{4}$ oz.	—
June 3	Fruitlet	As above	—	—
June 21	"3 weeks "	As above	—	—
July 6	"Codlin "	As above	DDT (a) 8 oz. Chlorbenside (a) $3\frac{1}{4}$ oz.	Dioctyl sodium sulpho-succinate (b) 2 oz.
Sept. 7	Pre-harvest	—	α -naphthalene acetic acid (b) 0.16 oz.	Dioctyl sodium sulpho-succinate (b) 3 oz.

(a) as benzene emulsion.

(b) as acetone solution.

The sprays were applied at approximately 275 gal./acre by a mobile spraying machine using two triple-nozzle brooms with 4/64 in. disc apertures, a short-range swirl plate in the centre, and two long-range swirl plates on the outside. The output of each broom was 6 gal./min. Details of the spray applications during 1954 are given in Table I.

Layout.

The trial was made on a 3-acre grass orchard of bush trees of the variety Cox's Orange Pippin, with the varieties Laxton's Superb and Winston as pollinators. The plot was initially laid out in 1947-48 as a trial on tree spacing and rootstocks, on which observations are continuing (6).

The plot contains 22 rows, running east to west, of the variety Cox's Orange Pippin, interspersed with Winston, as permanent bush trees on M.II rootstock, at a 24 ft. square plant. On the west side, there are 4 trees of Cox (2 Cox and 2 Winston in every third row), with trees nos. 1 and 6 as Laxton's Superb. On the east side a similar layout, ending with tree No. 11 as a Superb, has "fillers" of Cox (with Winston and Superb) on M.IX to give a 12 ft. square plant. The west side of the plot will be referred to as planting system IIA, and the east as IIB and IXB, respectively, to distinguish rootstocks. Each experimental plot consists of the full length of four rows, the centre two rows only being recorded; the three planting systems IIA, IIB, IXB are recorded separately. Double guard rows, parallel to the prevailing wind, are thus present between each recorded plot (but guards at the extreme ends of the plantation had to be dispersed with). The six available plots form three randomised blocks each of two plots. The layout of a typical plot is shown in Fig. 1. Treatments will be re-allocated in 1955 and 1956.

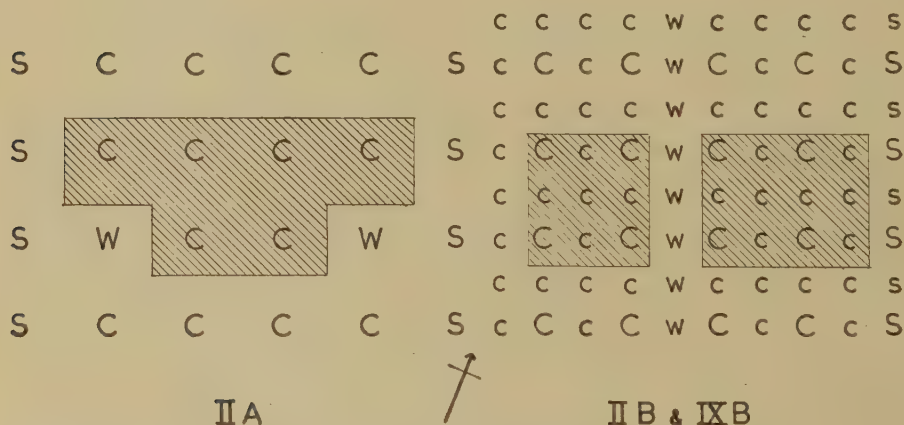


Fig. 1. Layout of a single plot. The shaded areas denote trees recorded.
C = Cox. W = Winston. S = Superb.
Small letters represent Type IX rootstock.

Methods of assessment.

Apple scab was assessed on fruits by Tehon and Stout's method, as amplified by Marsh (7). No assessment of leaf scab was made.

Apple mildew was estimated by an examination of ten shoots of the current season's growth on each tree, recording each shoot as infected (if any mildew observed), or healthy.

Crop weight was recorded for each tree to the nearest 0.1 lb.

Fruit russet, as percentage area of the total fruit surface, was estimated by visual comparison with models showing 10% and 25% area affected, in three categories:—

(A) Less than 10%. (B) 10% to 25%. (C) More than 25%.

Fruit size grading was carried out on a commercial machine.

Notes on weather.

The summer of 1954 was exceptionally wet, and was the fifth consecutive summer with rainfall above normal. The rainfall figures (in.) for each month are shown below, with normal values (1914–53) in brackets:—

April, 0.79 (2.33); May, 2.20 (2.59); June, 4.29 (2.11);

July, 4.05 (3.16); August, 3.32 (3.65); September, 6.08 (3.15);

Total, 20.74 (16.99). Excess over normal, 22%.

In addition, there was a marked deficiency of sunshine (29%) during the period June–August.

Nevertheless, scab was less severe than in 1953, probably due to the fact that a dry April, coupled with low temperatures during most of the rainy spells in May, delayed the onset of the attack. There was again heavy wood infection later in the season on unsprayed trees of the variety Cox's Orange Pippin elsewhere in the Long Ashton plantations.

Results.

On foliage.

Apple mildew was assessed on August 27–31, with the results summarised in Table II. Statistical examination of the data shows that in all planting systems the infection on captan plots was significantly greater (at the 0.1% significance level) than on the plots receiving lime sulphur throughout.

TABLE II.

PERCENTAGE OF SHOOTS OF CURRENT SEASON'S GROWTH SHOWING
MILDEW INFECTION, AUGUST 27–31, 1954.

Post-blossom fungicide	Planting system		
	IIA	IIB	IXB
Lime sulphur	3	3	4
Captan	23	30	18

On fruit.

The fruit of the variety Cox's Orange Pippin was picked on October 7–8. The total fruit from all trees in each recorded plot was bulked in three batches corresponding to planting systems IIA, IIB and IXB, and random samples of about sixty fruits were taken from orchard boxes by the method of Pearce (8).

Scab was assessed on these samples on October 14; the results are summarised in Table III. Owing to the very low incidence of scab, no statistical analysis was carried out.

TABLE III.
PERCENTAGE FRUIT AREA SCABBED ON SAMPLES, OCTOBER 14, 1954.

Post-blossom fungicide	Planting system		
	IIA	IIB	IXB
Lime sulphur	0.08	0.07	0.02
Captan	0.01	0.00	0.00

Fruit russet was also estimated on these samples; the results are summarised in Table IV. Statistical analysis of the data shows a highly significant difference (at the 0.1% level) between the spray treatments in each planting system.

TABLE IV.
DISTRIBUTION OF FRUIT RUSSET, OCTOBER 14, 1954.

Planting system	Post-blossom fungicide	No. fruit russeted in each category			Category (A) as percentage of total
		(A) <10%	(B) 10%-25%	(C) >25%	
IIA	Lime sulphur	103	52	4	64.8
	Captan	161	13	1	92.0
IIB	Lime sulphur	94	51	10	60.6
	Captan	135	5	2	95.1
IXB	Lime sulphur	86	94	38	39.4
	Captan	164	12	0	93.2

Crop weight was very variable, owing to the presence of many trees making vigorous growth and bearing little fruit. A summary of the results, omitting data from replants, is presented in Table V; no statistical analysis was carried out.

TABLE V.
MEAN CROP WEIGHTS (LB. PER TREE), EXCLUDING REPLANTS, OCTOBER 8, 1954.

Post-blossom fungicide	Planting system		
	IIA	IIB	IXB
Lime sulphur	33.6	40.1	32.5
Captan	50.5	28.7	32.4

Commercial grading was carried out on October 25 on the bulked crop. Data on fruit size are given in Table VI. Statistical analysis showed that in the planting systems IIA and IXB the captan-treated plots gave a significantly higher percentage (at the 5% level) of saleable fruit larger than $2\frac{1}{4}$ in. diameter. (In planting system IIB the same effect was apparent, but was not quite significant). The high proportion of unsaleable fruit is largely attributable to a short, but severe, hailstorm on August 21.

TABLE VI.

GRADING DATA : PERCENTAGE OF FIELD CROP IN EACH CATEGORY, OCTOBER 25, 1954.

Planting system	Post-blossom fungicide	Saleable fruit over $2\frac{1}{4}$ " diam.	Saleable fruit under $2\frac{1}{4}$ " diam.	Total saleable fruit	Unsaleable fruit
IIA	Lime sulphur	36.6	24.9	61.5	38.5
	Captan	51.6	21.7	73.3	26.7
IIB	Lime sulphur	38.7	30.5	69.2	30.8
	Captan	58.8	18.1	76.9	23.1
IXB....	Lime sulphur	35.3	22.8	58.1	41.9
	Captan	59.0	15.8	74.8	25.2

Incidental observations during the season suggested that *Cox spot* on leaves was worse on the captan-treated plots, and that there was little difference between spray treatments in their effect on *Botrytis* eye-rot of fruit.

Discussion.

The experiment as planned will continue for two further seasons, and besides the assessment each season of the "main" effect of each spray programme, the design permits an estimation of the "residual" effect from one year to another, and the cumulative result due to the application of either programme over two seasons. Thus, for example, a reliable assessment will be obtained of the long-term effects of captan on the build-up of apple mildew. It may also be possible to investigate the validity of the suggestion made in the technical press (9) that captan may tend to induce biennial bearing. The results will of course depend on the conditions prevailing in the three seasons, and to that extent no general deductions should be attempted until there has been adequate "replication in time."

Examination of the 1954 results shows that both programmes afforded an excellent control of apple scab in a season generally favourable to the disease. The substitution of captan for lime sulphur in the post blossom sprays resulted in a significant reduction in fruit russet and, in two of the planting systems, a significant increase in the percentage of saleable fruit greater than $2\frac{1}{4}$ " in diameter; on the other hand, the incidence of apple mildew was significantly higher. These findings are in general accordance with earlier results at Long Ashton (5) and with general experience throughout the country (10). The crop data should be viewed with reserve, owing to the high variability.

The captan concentration used ($1\frac{1}{2}$ lb. of a 50% preparation per 100 gal.) was below that generally employed, but was clearly adequate for scab control in this trial. Unpublished data suggest that by a further reduction in concentration to 1 lb. of 50% material per 100 gal. the limit of effective fungicidal performance is approached.

Summary.

The substitution of captan (0.075%) for lime sulphur (0.75%) in the post-blossom spray programme on the apple variety Cox's Orange Pippin resulted in a significant reduction in fruit russet, an improvement in fruit size, and a significantly higher incidence of apple mildew (caused by *Podosphaera leucotricha*). Both treatments afforded an excellent control of apple scab (caused by *Venturia inaequalis*).

Acknowledgments.

The authors wish to thank Mr. E. W. Hobbis and Mr. E. Catlow (for placing the trees at their disposal for this experiment, and for supplying detailed crop and grading data), Mr. R. W. Marsh (for his interest and suggestions during the trial) and Miss S. Freezer and Mr. P. Turner (for assistance in recordings).

The meteorological data were kindly supplied by Mr. G. E. Clothier.

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A SUMMARY OF APPLE SCAB CONTROL EXPERIMENTS AT LONG ASHTON, 1944-54.

By R. W. MARSH.

Twenty years ago, the fungicides generally used in Britain for the control of apple scab comprised only lime sulphur, Bordeaux mixture, sulphur suspensions and copper oxychloride (11). Within the following ten years, phenyl mercury chloride was introduced for apple scab control (15) and some preliminary trials were made at East Malling with tetramethylthiuram disulphide (thiram) and thiocarbamate sprays (16). During the 1939-45 war, further developments in the use of new fruit spraying materials made little progress in Britain, although progress in spraying methods was stimulated by the operation of the spray contract scheme (10).

Meanwhile, in the U.S.A., the thiocarbamates became well established as apple sprays in the early 1940's, and trials were made with substituted quinones, organo-mercurials, and glyoxalidine derivatives. From 1944 onwards, supplies of these recently-introduced fungicides were made more readily available in Britain and it became clear that the thiocarbamates and glyoxalidines were of special interest for application to sulphur-sensitive varieties (14). After 1949, trichloromethylthiotetrahydrophthalimide (captan) was added to the materials extensively tested in Britain.

The trials against apple scab made at Long Ashton since 1944 have included both comparisons of materials and comparisons of methods of spraying. The majority of the results have been obtained from replicated experiments on bush trees, usually 15-20 years old. The varieties chiefly used were Worcester Pearmain and Cox's Orange Pippin, but Lane's Prince Albert and Stirling Castle were included in phytotoxicity trials. When the main objective was assessment of the fungicidal performance of different materials, the trees were sprayed to the run-off stage with hand-directed hydraulic washes, using a programme of not more than four scab-control applications per season. In other trials, where methods of spraying were compared, some of the plots received air-flow applications at the rate of 50 to 100 gal. per acre. Detailed accounts of the lay-outs and programmes are given in the papers to which references are made below.

Assessment of materials.

Thiram and thiocarbamates.

In 1944 (1) ferric dimethyldithiocarbamate (ferbam) was applied to Cox trees on 30th June in a wash containing 2 lb. of 60% ferbam, 1 gal. Grade G oil emulsion and 1 lb. DDT, per 100 gal. Comparable trees were sprayed with a corresponding wash containing 4 pt. copper oxychloride suspension (16% Cu) in place of the ferbam. In this trial scab infection was negligible but the phytotoxic effects were noteworthy. The copper-oil mixture induced 90% defoliation and 36% disfiguring fruit russetting. The ferbam-oil caused no russetting and only slight defoliation. The ferbam, however, left a conspicuous black residue which persisted on the apples as unsightly black blotches, still apparent at the time of harvest.

In 1945 (7) trials were made on Worcester, Lane and Superb, using both ferbam and thiram, with oil and with 0.2% sulphite lye, in comparison with lime sulphur. Applications were made on 13th April, 18th May and 26th June. All the fruit in this trial was destroyed by a frost on 30th May, but an assessment of mean percentage scabbed area per leaf in August gave the following results: lime sulphur 0.28, thiram 0.75, ferbam 1.23. There was no evidence from this trial of damage due to the thiram or ferbam suspensions in dilute sulphite lye: considerable leaf damage was done by the oil, but this was not accentuated by the addition of either fungicide.

In 1951 (6) zinc dimethyldithiocarbamate (ziram), which does not leave a disfiguring residue, was included in a trial on Worcester Pearmain, in comparison with thiram and lime sulphur. The sprays were applied on 11th May, 4th June and 4th July, the concentrations per 100 gal. being 3 lb. of 80% ziram, 3 lb. of 80% thiram, and lime sulphur at 2% pre-blossom and 1% post-blossom.

In this trial all three materials gave excellent scab control without significant difference, the mean percentage scabbed area on fruits being 0.02 for ziram, 0.03 for lime sulphur and 0.07 for thiram (unsprayed, 0.78%). No damage to foliage was recorded, but the figures for percentage fruit russeted were: unsprayed 0, lime sulphur 6, thiram 16, ziram 21. The high russetting figures on Worcester Pearmain sprayed with thiram or ziram are noteworthy.

Phenyl mercury preparations.

The first post-war trial with a mercury spray at Long Ashton was made in 1946 (12) using 'mercurated arsenate' (2.5% phenyl mercury chloride incorporated with lead arsenate) plus a sulphite lye wetter. This material was applied to Worcester Pearmain at 2 lb. per 100 gal. in comparison with lime sulphur 3% pre-blossom and 1% post-blossom. Persistent wet weather prevented the inclusion of a petal-fall spray and the dates of application were 18th April, 29th April and 23rd July. The result of this bad timing was a heavy scab infection, showing no significant difference between the two treatments (55.5% of fruits scabbed in lime sulphur blocks; 63.5% following mercury spraying). No spray damage was recorded, but the failure of the mercurial spray to check red spider infestation was obvious.

In 1951 (6) three mercurial preparations were compared on Worcester at the same mercury concentration—0.002% Hg. (This strength is below that usually recommended for organo-mercury sprays). The materials used were phenyl mercury chloride, phenyl mercury acetate, and the diphenyl mercuric salt of di-2:2'-naphthylmethane-3:3'-disulphonic acid. The last-named is highly water-soluble. The sprays were applied on 11th May, 4th June and 4th July in comparison with lime sulphur at 2% pre-blossom and 1% post-blossom.

The resulting figures for mean percentage fruit area scabbed were: lime sulphur 0.03, phenyl mercury chloride 0.26, soluble organo-mercury sulphonate 0.26, phenyl mercury acetate 0.30, control 0.78. The three mercury preparations thus gave equal scab control in this trial but, at the strengths used, were less effective than lime sulphur applied at the same times. No russetting or other damage resulted from the mercury applications.

In the following year (3) the same three mercury preparations were compared at 0.0032% Hg, again on Worcester. The sprays were applied on 8th May, 26th May and 25th June. The scab infection results, expressed as in 1951, were : lime sulphur 0.01, phenyl mercury acetate 0.04, phenyl mercury chloride 0.19, soluble organo-mercury sulphonate 0.68, control 1.16. Increase in the concentration of the mercurials, as compared with the 1951 levels, placed the phenyl mercury chloride and phenyl mercury acetate sprays on the same level of scab control as lime sulphur, but the soluble organo-mercury sulphonate remained less effective as a protectant.

A phytotoxicity trial made in 1952 using three applications of phenyl mercury chloride at 0.0032% Hg. on Lane and Stirling showed no damage to either variety.

Substituted quinones and quinolines.

A preparation of 2:3-dichloro-1:4-naphthaquinone (dichlone) was used in 1950 on Worcester (5). Applications were made on 28th April and 18th May using 0.05% dichlone plus 0.05% magnesium sulphate. Lime sulphur (2%, then 1%) was used for comparison. Fruit recording on 23rd August showed 0.06% scab for the dichlone plot, 0.02% for lime sulphur and 0.26% for the comparable unsprayed trees. No phytotoxicity was noted in this trial, but in an experiment on brown rot control (2) the dichlone spray applied on 12th July and 16th August induced a slight green blotchiness on fruits of Cox, Rival and Laxton's Superb.

In 1947, 8-hydroxyquinoline sulphate monohydrate was used at 1 lb. per 100 gal., with 4 oz. hydrated lime, on Worcester trees. Applications were made on 25th April, 9th May and 22nd May, in comparison with lime sulphur (3%, 3%, 1%). The results showed that the hydroxyquinoline treatment was completely ineffective in controlling apple scab, the fruit infection figures being : lime sulphur 0.07, hydroxyquinoline 0.43, control 0.48 (12).

Glyoxalidines.

From 1946 to 1950 a number of different preparations of glyoxalidines were in use, but the only formulation now remaining available is a 34% preparation of 2-heptadecyl glyoxalidine acetate (glyodin). The present review deals only with trials made with this material. A preliminary trial in 1947 (12) using commercially pure glyodin at 1 lb. per 100 gal. showed that it equalled lime sulphur (3% pre-blossom, 1% post-blossom) in scab control on Worcesters. In 1951, the 34% glyodin was used at 3 pt. per 100 gal. with 8 oz. hydrated lime added : this spray was applied to Cox on 3rd May, 5th June and 14th July, in comparison with lime sulphur 2% pre-blossom and 1% post-blossom. The two fungicides gave equal scab control (glyodin 0.45%, lime sulphur 0.49%, unsprayed 1.01%).

In 1952 the treatments were repeated on the same blocks (3) on 28th April, 26th May and 1st July, and the performance of the two fungicides was again equal (glyodin 0.12%, lime sulphur 0.09%, unsprayed 3.39%). In the following year (4) the glyodin spray was applied post-blossom only on Lane's Prince Albert on 21st May, 15th June and 15th July. The figure for fruit scab on 9th September was 0.08%, in comparison with 0.03% for captan (see below).

Phytotoxicity trials with glyodin have shown varying results, apparently depending on the weather during the summer months. In the hot dry summer of 1949, when the April-September rainfall was only 12.6 in., 34% glyodin at 1 qt. per 100 gal., applied on 30th May and 20th June, gave the following results in comparison with lime sulphur.

TABLE I.
MEAN FRUIT COUNTS PER TREE, 1949.

Post-blossom treatments	Variety	
	Cox	Stirling
Nil	416.5	292.5
Glyodin 1 qt./100 gal. ..	196.2	97.5
Lime sulphur 1%	198.3	6.0

In contrast, the results in 1951, when the April-September rainfall was 17.2 in., are shown in Table II.

TABLE II.
MEAN FRUIT COUNTS PER TREE, 1951.

Treatments (3rd May, 6th June, 3rd July)	Variety		
	Cox	Stirling	Lane
Nil	569	341	455
Glyodin 3 pt./100 gal. ..	710	222	441
Lime sulphur 2%, then 1%	763	not tested	not tested

In 1952, following sprays on 28th April, 26th May and 25th June, the crop of Cox was recorded, with the following result, expressed as mean numbers of orchard boxes per tree : glyodin 2.25, lime sulphur 1.41, control 1.67.

Considering the whole range of the phytotoxicity trials made with glyodin at Long Ashton, it must be concluded that the damage recorded in 1949 was exceptional. In the six other years in which it was used, glyodin caused negligible or no damage to Cox.

A secondary effect of the use of glyodin is its influence on apple mildew. While this disease is held in check by the standard lime sulphur applications, it is not controlled by glyodin. Table III shows the incidence of mildew on a Cox plot where glyodin and lime sulphur treatments were compared in a 3-year trial.

TABLE III.

EFFECT OF SCAB FUNGICIDES ON INCIDENCE OF APPLE MILDEW
ON COX'S ORANGE PIPPIN.

Treatment for three successive years	Mean % new shoots infected in July
Glyodin 0.375%	36.8
Lime sulphur 2% pre-blossom ..	15.0
1% post-blossom ..	
Control	42.0

Captan.

Captan first became available in 1950, as a wettable powder containing 50% N-trichloromethylthiotetrahydrophthalimide. This formulation, at 2 lb. per 100 gal., was applied to Worcester Pearmain, Lane's Prince Albert and Stirling Castle in 1950, 1951 and 1952 and to Cox in 1952 and 1953 (3, 4, 5, 6).

Table IV summarises the records, for Worcester and Cox, of scab control following this captan treatment, together with the comparable results obtained from lime sulphur and from unsprayed trees.

TABLE IV.

SCAB INFECTION ON FRUITS OF WORCESTER AND COX FOLLOWING
SPRAYING TREATMENTS IN 1950, 1951, 1952 AND 1953.

Variety	Year	Dates of application	Mean % scabbed area on fruits sprayed with		
			Captan 0.1%	Lime sulphur 2%, then 1%	No spray
Worcester ..	1950	28/4, 18/5	0.01	0.02	0.26
" ..	1951	7/5, 5/6, 3/7	0.07	0.34	0.80
" ..	1952	28/4, 26/5, 25/6	0	0	0.46
Cox ..	1952	28/4, 26/5, 25/6	0.08	0.09	1.83
" ..	1953	22/4, 25/5, 19/6	0.91	1.90	5.10

This table shows that captan surpassed lime sulphur in fruit scab control in 1951 on Worcester and in 1953 on Cox: in the other trials listed the performance of the two fungicides against scab was equal.

In the phytotoxicity trials captan induced no damage on Lane and Stirling. In the experiments on Cox noted in Table IV the mean yields per tree following the 1952 treatments were: captan 3.23 orchard boxes, lime sulphur 2.54, unsprayed 1.40. In 1953, the figures were (in bushels): captan 2.8, lime sulphur 0.5, unsprayed 0.2. It is probable that in 1953 the heavy scab infection on the lime-sulphur-sprayed plot had more effect than sulphur injury in reducing yield.

The 1954 trials on Cox are described on pp. 147–152 of this *Report*. In these captan was used, post-blossom only, at $1\frac{1}{2}$ lb. of the 50% preparation per 100 gal., in comparison with $\frac{3}{4}$ % lime sulphur. Scab infection was negligible in this trial but the incidence of disfiguring russet and cracking was more than twice as high on the lime sulphur blocks as after captan. When the fruit was graded, 58% of the captan-sprayed fruit was placed in the extra-fancy and fancy grades; the corresponding figure for lime sulphur was only 34%. Counts in the late summer showed a marked increase in apple mildew in the captan-sprayed blocks.

In another trial on Cox, lime sulphur was used at 2% pre-blossom (once) and at $\frac{3}{4}$ % post-blossom (twice). Captan (50%), in comparison, was used at 2 lb. pre-blossom and 1 lb. post-blossom. The resulting scab infection ratings on the fruits were 0.13% for lime sulphur, 0.19% for captan and 0.59% for the unsprayed controls.

Assessment of spraying methods.

The trials listed in the preceding section employed only large-volume, hydraulic spray applications, i.e. washes applied through hand-directed lances in drenching amounts. A major recent development in spraying methods is the utilisation of much smaller volumes applied as minute droplets impelled by a high-velocity airstream. The concentrations used in such air-flow applications are frequently, though not invariably, higher than those in the large-volume washes.

The objective of the experiments summarised below was the assessment of the value of air-flow applications for the field control of apple scab. This work is still at an early stage and has been confined at Long Ashton to air-flow applications of 100–200 gal. per acre using lime sulphur in the range $\frac{3}{4}$ % to 4%.

1952 trials. In a preliminary experiment made on trees of Worcester Pearmain (8), 1% lime sulphur hydraulically applied at 400 gal. per acre was compared with air-flow sprays of 2% lime sulphur at 200 g.p.a. and of 4% at 100 g.p.a. All treatments were given on 13th May, 20th May and 4th June. The large-volume spray gave the best scab control (0.09% scab on fruit), the corresponding figure for the 4% air-flow spray being 0.22% and for the 2% air-flow spray 0.51%; with 3.15% for the unsprayed plot. The 4% spray caused serious fruit drop in this experiment, but this effect has not recurred in later trials.

Also in 1952 trees of Cox sprayed with 1% lime sulphur at 650 gal. per acre on 5th May, 21st May, 7th June, 19th June and 7th July were compared with trees given air-flow applications of 1% lime sulphur at 100 g.p.a. on the same dates. The scab control assessment, made on the foliage, showed 0.03% for the large-volume sprays, 0.29% for the small-volume. The trees given the air-flow treatments yielded 347 fruits per tree, compared with 171 on the large-volume plot.

1953 trials. In 1953 (9) all the air-flow applications were at 100 gal. per acre of 1% or $\frac{3}{4}$ % lime sulphur: the large-volume sprays were at the same strengths but at a minimum of 480 g.p.a. On Worcesters there were four air-flow applications (30th April, 18th and 28th May, 23rd June): the late-May treatment was omitted from the large-volume programme. The resulting fruit scab figures were 0.24% for large volume, 0.84% for air-flow, 2.11% for unsprayed.

On Cox, a similar comparison was made between large-volume and air-flow methods, using two pre-blossom applications at 1% lime sulphur and two post-blossom at $\frac{3}{4}$ %. In a wet summer the large-volume programme gave almost perfect scab control but the air-flow sprays were ineffective, over two-thirds of the crop being scabbed. The heavy scab attack also seriously reduced the yield in the air-flow block.

1954 trials. The experience of 1953 demonstrated that a programme of four air-flow sprays using 100 gal. per acre of 1% lime sulphur was inadequate. The 1954 trials, reported elsewhere in this *Report* (p. 134), assessed the effects of extending the programme and of increasing the spray concentration. It was found that six air-flow applications of 1% lime sulphur were considerably more effective than five, while six applications at 2% strength gave a level of scab control approaching that obtained by five high-volume sprays at 1%. The air-flow treatments induced very little russetting, whereas in 1954 the high-volume sprays caused such extensive russetting and cracking on Cox in this trial that half the crop was rendered almost valueless.

Discussion.

One of the features demonstrated in this survey of apple scab trials, made largely on the same plots for a period of several years, is the seasonal fluctuation in the incidence of the disease. These fluctuations, mainly the effect of weather, usually make it impracticable to assess the merits of a fungicide or a method of application without repeated trials. On the other hand, a phytotoxic effect may become apparent in a single field experiment.

Because of this necessity for extended trials, it is not possible, from the results given in this paper, to reach final conclusions on the value of thiram and the thiocarbamates (ferbam and ziram) for apple scab control. The disfiguring effect of ferbam is an obvious disadvantage, and the record of performance of thiram shows the inconsistencies that were earlier reported from East Malling (16). Ziram gave excellent scab control at Long Ashton in 1951, but its tendency to induce russetting is disquieting.

The quinone and quinoline derivatives have had only preliminary field tests. In a single trial, 8-hydroxyquinoline proved of no value against apple scab. Dichlone (dichloronaphthaquinone) was an effective fungicide, but it has frequently been recorded as phytotoxic and it is also a potential skin irritant.

The organo-mercury fungicides are now well established as a means of controlling scab in commercial orchards, and the Long Ashton trials were made only to elucidate certain points of detail in their performance. It is often presumed that their effect is only eradicant and of limited duration, but it is noteworthy that in the 1953 trial phenyl mercury chloride and phenyl mercury acetate gave a high level of control with only three applications at 3- to 4-week intervals. This suggests that these relatively insoluble materials possess protectant as well as eradicant properties.

The glyodin preparations were given extensive trials, in which they proved approximately equal to the standard lime sulphur sprays in scab control. Except in the hot, dry summer of 1949 they have caused no damage to sulphur-sensitive varieties, but they are of no value against apple mildew.

Captan, used at 2 lb. of the 50% product per 100 gal., has shown an excellent record in five successive years. In 1951 and 1953 it was exceptional in surpassing lime sulphur in scab control. In 1954 the 50% captan, used

post-blossom at $1\frac{1}{2}$ lb. per 100 gal., was equal to $\frac{3}{4}\%$ lime sulphur : at 1 lb. per 100 gal. it was slightly inferior. Up to the present, no damage from this sp. has been noted in the Long Ashton trials but, like glyodin, it has no effect on apple mildew. This is a serious limitation to its value and may entail its employment for part of the season only.

Lime sulphur has been employed through these trials as a standard for reference, usually at 2% pre-blossom and 1% post-blossom, but in certain of the 1954 trials at not more than 1% throughout. A programme of 3-5 applications, applied as lance-directed drenching sprays, has given a high level of scab control except in 1953 and in 1946, when the timing of the sprays was known to be faulty. No evidence has appeared in these trials of any diminution in the general level of effectiveness of this material against the apple scab fungus. In commercial fruitgrowing in Britain the major objection to the use of lime sulphur in large-volume applications is its potentiality for causing fruit-drop and russetting on Cox in certain seasons.

Regarding methods of application, the requirements in labour and time of hand-directed large-volume spraying have directed attention to automatic small-volume applications. The term "small-volume," covers a wide range, and is used in the present paper to signify applications, in an air-stream of approximately 10,000 cu. ft. per minute, of droplets of lime sulphur at not more than 4% strength, at volumes between 50 and 100 gal. per acre. Within these limitations, the evidence so far available suggests that six air-flow applications per season of 2% lime sulphur provide satisfactory scab control on bush trees of Cox. These small-volume applications are far less damaging on this variety than large-volume lime sulphur sprays at $\frac{3}{4}\%$ and over.

In considering the possible future developments of the apple spraying programme it is clear that the extension of small-volume spraying to other fungicides will raise problems in the use of suspensions which have not arisen in using lime sulphur. The requirements of the scab control programme must also be considered in relation to the need for controlling red spider, a pest that is not kept in check by small-volume applications of lime sulphur or by fungicides other than lime sulphur. The necessity for obtaining an almost perfect cover with the materials now being used for red spider control is a difficulty that is becoming apparent in the attempts to develop a programme of small-volume spraying that will provide a combined fungicidal and acaricidal effect.

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THE ROLE OF ERADICANT FUNGICIDES IN THE CONTROL OF APPLE CANKER :

III. A SUPPLEMENTARY NOTE.

By R. J. W. BYRDE and A. T. K. CORKE.

The preceding papers in this series showed that 0.3% phenyl mercury chloride, used as an eradicant spray in late autumn, suppressed the sporulation from cankers of *Nectria galligena* Bres. for a considerable period. A detailed examination of sample cankers in the laboratory indicated that sporulation was still inhibited after sixteen months, although the growth of the fungus in untreated cankers in the field continued unchecked (2, 3).

The present paper gives the results of laboratory examination of treated cankers continued until the re-establishment of perithecial formation.

Experimental.

Materials. The formulation of the spray materials and their dates of application have already been described (3).

Estimation of Results. The viability and sporulation of the fungus were assessed as before, but the intervals between examination were extended because of the increasing shortage of treated cankers. Care was taken to examine only cankers considered old enough to have been treated. No cankers treated with sodium pentachlorophenate were available.

Results.

The results obtained in 1954 are summarised in Table I.

TABLE I.

VIABILITY AND SPORULATION OF *N. GALLIGENA* IN TREATED CANKERS.
Four cankers per treatment.

Date collected	Treatment **	Spore concentration ($\times 10^3$)		Percent. germination (same concentration)		Date of laboratory examination	Cankers showing mycelial growth	Cankers showing perithecia
		Conidia	Ascospores	Conidia	Ascospores			
8/3/54	Control	—	0.01	—	100*	12/5/54	4	0
	Pcp.	—	0.01	—	20*		4	1
	PMC	—	0.01	—	0*		3	0
12/5/54	Control	33.3	36.6	75*	75*	19/11/54	0	0
	Pcp.	26.6	23.3	75*	75*		2	0
	PMC	30.0	6.6	60*	60*		2	3
7/12/54	Control	—	390	—	99.5	9/12/54	0	4
	Pcp.	—	190	—	95		0	4
	PMC	—	55.4	—	93		0	4

** Pcp. = Pentachlorophenol 0.7%, Feb. 1952.

PMC = Phenyl mercury chloride 0.3%, Nov. 1951 and Oct. 1952.

0 Examined without incubation owing to number of perithecia already present.

* Approximate counts — too few for standard tests.

Discussion.

The previous paper (3) gave the results of the application of phenyl mercury chloride (0.3%) in November 1951 and October 1952 to apple cankers caused by *N. galligena*. The treatment reduced the sporulation of the fungus without unduly affecting its growth within the tissues of the host.

This effect was still apparent in December 1953, but the results of subsequent examinations presented above indicate that re-establishment of sporulation took place during the spring of 1954, some eighteen months after the last treatment.

This result is in accord with those given in earlier papers (1, 2), where it was shown that the effect of phenyl mercury chloride on sporulation persisted for a period of about fifteen months. It appears that this approaches the maximum effective period that can be expected to follow an autumn application.

Summary.

The sporulation of *Nectria galligena* on cankers treated with 0.3% phenyl mercury chloride in the autumn was reduced for a maximum period of about eighteen months, after which normal sporulation was re-established.

Acknowledgments.

The authors wish to thank Miss M. Marlow for her valuable help in the recording of results.

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BITTER ROT OF APPLES:

I. BRANCH INOCULATIONS WITH *GLOEOSPORIUM PERENNANS* AND *G. ALBUM*.

By A. T. K. CORKE.

Recent increases in the losses incurred during the storage of apples have directed attention to the high proportion of rots due to *Gloeosporium perennans* Z. & C. and *G. album* Osterw., and have led to investigations of their distribution in the orchard.

Wilkinson, in 1943 (4), first recorded *G. perennans* in Britain, both on fruit and branches. He noted that it induced cankers on many varieties of apple tree, and that the damage was particularly severe on trees pruned in the summer (4, 5). In one plantation, he recorded that the substitution of winter for summer pruning virtually eliminated *Gloeosporium* cankers.

G. album was first reported on fruit in England by Kidd and Beaumont in 1924 (1), and noted by Ogilvie in 1935 as a saprophyte becoming increasingly common on dead pruning snags of apple (2).

Work at Long Ashton on the orchard phases of infections by *Gloeosporium* spp. was resumed in June 1953. To ensure a supply of cankers of known history, a series of monthly inoculations was begun. The results given below record the establishment and rate of growth of the cankers initiated during the subsequent thirteen months.

Experimental.

Lay-out.

Seventy-five 8-year-old dwarf pyramid apple trees of the variety Cox's Orange Pippin were used. They were planted at 4 ft. intervals in two rows 10 ft. apart, running north and south. One row was taken for *G. album* inoculations and the other for *G. perennans*.

Each row was divided into five blocks of seven trees, and monthly inoculations were made successively on one tree in each block, beginning again in January 1954 with those previously inoculated in June.

In each series, two inoculations with mycelium and four with a spore suspension were made on each tree, giving a total of ten mycelial and twenty spore suspension inoculations per month on each row. The mycelial inoculations were made by inserting a small piece of mycelium on agar under the tongue of a V-shaped cut, and the spore suspensions were applied as drops placed on the freshly-exposed surface of shoots cut close to a larger branch. The instruments used and the sites of inoculation were wiped with methylated spirits before cutting the bark; immediately after inoculation the wounds were covered with a strip of self-adhesive crêpe rubber. Of the inoculations made in 1953, half were uncovered after 10 and half after 20 days; those made in 1954 were left covered for 20 days. Records were made each month of the number of cankers newly appearing (Table I) and the length of all established cankers.

The inoculum was obtained from cultures grown on malt or potato dextrose agar at 5° C. Sporing tube-cultures were selected each month, a little 1% dextrose solution was added and the tubes were then agitated. The spore

suspensions thus obtained were diluted to a concentration of approximately one million spores per millilitre. Mycelium for use as inoculum was, wherever possible, taken from the same cultures that provided the spore suspensions.

Results.

TABLE I.

CANKERS INDUCED BY INOCULATIONS WITH *G. PERENNANS*.

Month of inoculation	Type of inoculum used											Total cankers
	Mycelium (10 inoculations)				Spore suspension (20 inoculations)							
	Cankers newly appearing in successive months after inoculation			Total cankers	Cankers newly appearing in successive months after inoculation							
	1st	2nd	3rd		1st	2nd	3rd	4th	5th	6th		
1953—												
June	9	—	—	9	—	—	—	—	—	—	—	0
July	10	—	—	10	—	—	—	—	—	—	—	0
August ..	10	—	—	10	—	—	—	1	—	—	—	1
September ..	10	—	—	10	1	—	—	—	—	—	—	1
October ..	9	—	—	9	—	—	—	—	—	—	—	0
November ..	8	2	—	10	7	8	—	2	1	2	—	20
December ..	10	—	—	10	1	1	4	7	1	—	—	14
1954—												
January ..	—	8	2	10	—	—	1	—	—	—	—	1
February ..	9	1	—	10	—	—	—	—	—	—	—	0
March	10	—	—	10	3	2	—	—	—	—	—	5
April	10	—	—	10	1	—	—	—	—	1	—	2
May	*	10	—	10	*	1	1	—	—	—	—	2
June	10	—	—	10	—	—	—	—	—	—	—	0

*Not examined.

Table I shows that inoculations with mycelium of *G. perennans* were successful throughout the year, whereas those with spore suspensions produced cankers mainly in November (100%) and December (70%). Cankers also resulted from inoculations with spore suspensions in March (25%), April and May (10%) and August, September and January (5%).

The observations on the growth of the cankers in the first three months following successful inoculations are given in Fig. 1. This shows that cankers arising from inoculations in the period March-August made little or no further growth after the two months following initiation. Such a rapid decrease in

the growth rate did not, however, occur in the cankers initiated in the period September-February: these continued to grow until the period May-August (not shown in Fig. 1). Cessation of canker growth was normally marked by the formation of callus tissue, and only three of the cankers produced in this experiment showed growth beyond the callus layer.

Irrespective of the month of inoculation, the increase in growth of all cankers was greatest in March, slightly less in April and May and considerably less in June. After a rise in July, the rate of growth diminished gradually until September, rose steadily until December, and again fell to a low level in February.

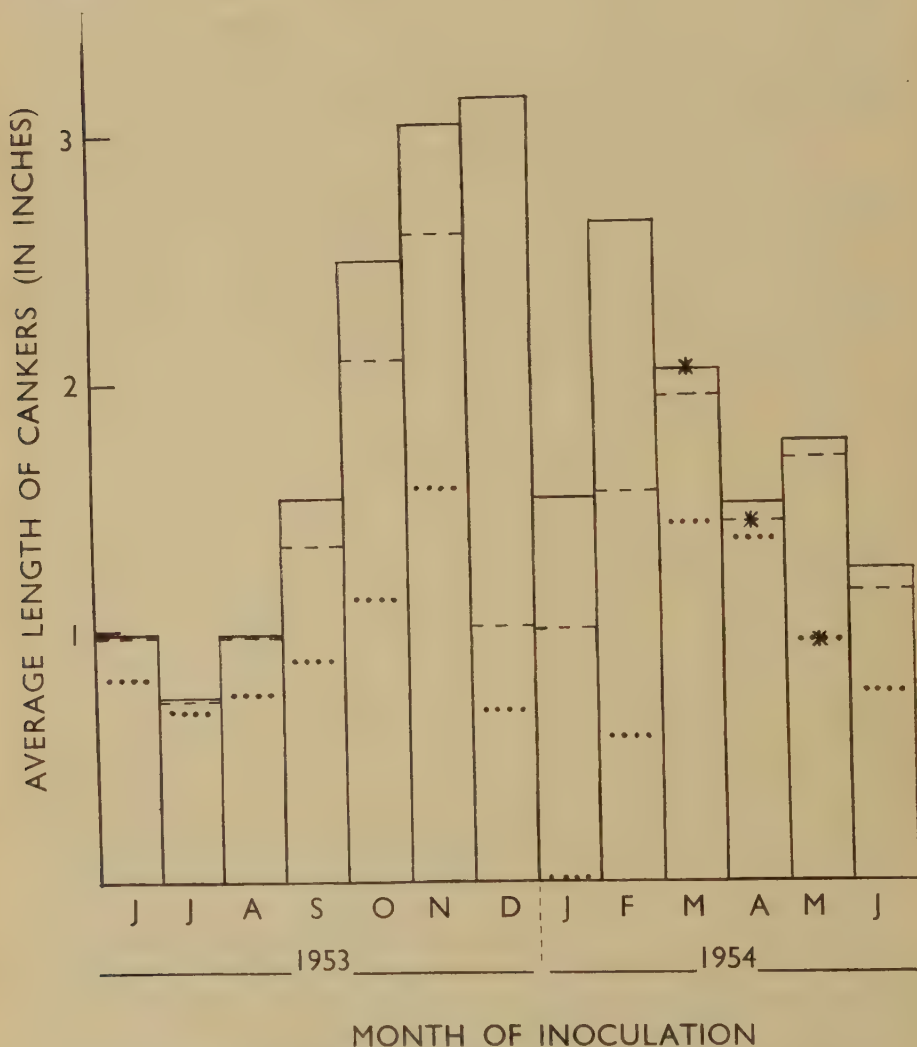


Fig. 1. Records of first three months' growth of cankers induced by inoculations with mycelium of *Gloeosporium perennans* :—
 growth after 1 month.
 — — — growth after 2 months.
 ————— growth after 3 months.
 * estimated.

In the inoculation experiments with *G. album*, infections were obtained only in the late summer, producing a small number of cankers that developed in mid-winter. Only 20% of these August and September mycelial inoculations and 10–15% of the July and August spore inoculations were successful. No development of cankers was seen before November and their growth ceased after 2–3 months, when none had grown more than 1 inch. The healing of the host tissues round these cankers was complete by the spring and, in the absence of spore pustules, no positive identification of the causal organism was made.

Discussion.

The results given above are in agreement with those of the inoculation experiments carried out by Wilkinson in 1945 (5). He noted that cankers induced on the wood of Cox's Orange Pippin by inoculations with mycelium of *G. perennans* in November grew rapidly at first and became occluded by callus by April. Cankers induced by inoculations in May grew more slowly and were stopped in mid-summer by the formation of callus.

In reporting field observations on trees receiving no artificial inoculations, Wilkinson noted the absence of *Gloeosporium* infections of winter pruning cuts and the liability to infection of wounds made in the summer (6). In the investigations reported in the present paper the inoculations with spore suspensions (approximating to natural inoculations in the field) were generally successful only in November–December. Wilkinson's field records of lack of infection following winter pruning may have referred to a pruning period in January–February, or may have been associated with an absence of spore inoculum.

The suggestion that summer pruning is necessarily associated with a high level of *Gloeosporium* infection is not supported by the results of the spore inoculation experiments described above. The relatively low rates of growth in all the measured cankers during August and September showed that host resistance at this time was high and that infected tissues were likely to be rapidly isolated by callus. The evidence therefore suggests that the risk of infection of pruning cuts by *Gloeosporium perennans* was much higher in November–December 1953 than in January–February 1954.

While the present investigation has thrown light upon the establishment and growth of *G. perennans* cankers on apple branches throughout the year, it has provided little information on the life cycle of *G. album*, on which further studies on orchard distribution are planned.

Summary.

Monthly inoculations of branches of Cox's Orange Pippin with *Gloeosporium perennans* and *G. album* were made at Long Ashton from June 1953 to June 1954. Inoculations with mycelium of *G. perennans* were successful throughout the year. Inoculations made with spore suspensions were, however, generally successful only in November and December.

All inoculations made with *G. album* were ineffective except in July–September when a small proportion induced short-lived, non-sporing cankers.

Acknowledgments.

Grateful acknowledgment is made to Mr. R. W. Marsh for his interest and advice throughout this work ; to the Ditton Laboratory for supplying the material from which the species of *Gloeosporium* were isolated ; and also to Miss M. Marlow and Miss N. Waugh for help in making the inoculations and recording the results.

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SMALL-VOLUME AIR-FLOW SPRAYING FOR THE CONTROL OF POTATO BLIGHT.

By H. G. H. KEARNS and N. G. MORGAN.

The preliminary trial described was carried out in 1950 to assess the efficacy of small-volume air-flow spraying for Blight control.

A 2.4 acre block of potatoes (var. mainly Dunbar Standard) 129 yd. $\times$ 108 rows at 2 ft. 6 in. apart was used for the trial, five rows on the east side being left unsprayed. The copper fungicide used was a proprietary formulation of a basic carbonate containing its own dispersing agent: the copper concentration was 0.88%. No additional wetting agent was used. The spraying machine used was the experimental one described on page 97 of this Report but fitted with six $\frac{3}{4}$ in. B.S.P. spray nozzles with discs of $1\frac{1}{2}/64$ inch diameter aperture and small-volume swirl plates.

Eight-row blocks of potatoes were sprayed from two opposite sides, the spray droplets being blown across the rows at right angles to the direction of travel. The fan performance and the wind speed determined the "swath" width. In the earlier stages of growth the foliage was disturbed by the air stream and the undersides were exposed to the spray droplets. Later in the season the plants were bent in the path of the air-stream and the fungicide was deposited mainly on the undersides of the foliage throughout the length of the haulm. A swath of eight rows was chosen because this represented the distance throughout which the plants were moved by the air-stream, although fungicide was deposited beyond this limit.

The fungicide applications were made on July 19th and 26th, and on August 9th and 16th, at a mean rate of 10 gal. per acre.

On August 21st counts of the leaflets showing blight areas were made on random sample plants in the sprayed and unsprayed rows. The crop was lifted on October 9th and the weight of tubers from five rows each of the sprayed and unsprayed blocks recorded. Results are shown in Table I.

TABLE I.

	Sprayed	Unsprayed
Mean no. compound leaves per plant	52.08	50.45
Mean no. leaflets per plant	364.56	353.15
Mean no. blighted leaflets per plant	166.0	350.0
Per cent. blighted leaflets	45.06%	98.98%
Crop weight from five rows	1260 lb.	823 lb.
Crop weight per acre	5.02 tons	3.28 tons

No attempt was made to assess the degree of infection at the time of the leaflet counts but comparing the appearance of the plants in early September

with that indicated in the blight assessment key (1) infection was approximately 95% on the unsprayed and between 5% and 25% on the sprayed blocks.

The small-volume air-flow method offers a solution to some of the problems at present associated with potato spraying. The operational time could be reduced by the use of larger air outputs thereby increasing the effective swath width and, at the same time, reducing mechanical damage to the crop. Further work is required to establish whether or not spraying of the rows from two directions is necessary.

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A PROTOTYPE LEAF-SAMPLING DISC-CUTTER.

By N. G. MORGAN.

Many field investigations on crop plants, particularly those concerned with the measurement of spray deposits, require the collection of large numbers of leaf samples. Several methods of collecting the samples are available, depending upon the information desired, but the most convenient one for many purposes is the cutting of discs of uniform area from the leaves. Usually this is done with a cork borer, the leaf being supported beneath by a piece of wood or similar material. In this method the discs, unless frequently removed, become progressively more tightly packed in the borer and may require considerable pressure to eject them with a rod or plunger. In some cases, in the examination of Fruit Tree Red Spider Mite on apple leaves, for example, packing of the discs may be undesirable.

The sampling tool here described was designed to fulfil the major requirements of efficient leaf disc sampling *viz.* positive and rapid cutting of the discs and their ejection into the sample container without packing.

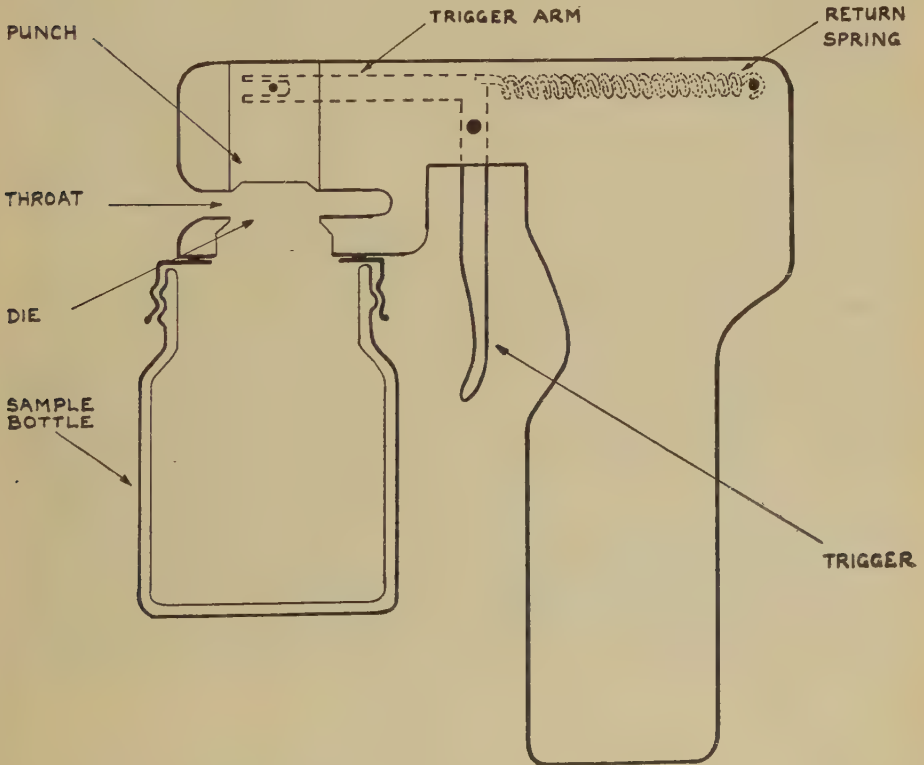


Fig. 1.

Diagram of the prototype leaf-sampling disc-cutter.

The principal features of the tool are shown in Fig. 1. The leaf, when inserted into the throat, is depressed by a trigger-operated punch which, on meeting the resistance of a die, cuts a disc and ejects it into a sampling bottle temporarily screwed to a lid fixed to the base of the tool. The spring returns the punch for the next cut on release of the trigger. The operation is repeated until the required number of discs have been collected, when the bottle is removed and the next one is screwed on. The disc cutting is therefore continuous, apart from momentary replacement of the bottle. Plate XII shows the cutter in operation.

Construction.

The prototype cutter body was made from a cast aluminium block which was bored, reamed and lapped to take the 20 mm. diameter cylindrical brass punch as a sliding fit. The bolster (below the die) was counterbored to allow free fall of each disc as it was cut. A $\frac{1}{4}$ " wide horizontal slot was then milled transversely across the body to a depth beyond the plunger bore to form the throat, the outer edges of which were chamfered to facilitate edgewise entry of the leaves. A recess machined in the cutting end of the punch ensured that pressure was applied to the leaf only on the perimeter of the disc. A $\frac{1}{8}$ " wide slot was milled in the other end of the punch to take the trigger arm which was also slotted to allow relative movement between it and the punch thrust pin. A vertical slot milled longitudinally in the top of the body, and a transverse one meeting it from the base, accommodated the trigger arm and return spring assembly. The trigger pivot pin was placed in a position mid-way between the levels of the upper and lower limits of movement of the punch. The hardwood handle was slotted to take the return spring attached to the trigger arm and was bolted to the body.

The most important points in the construction of the cutter are :—

- (1) Accurate alignment of punch barrel with the die.
- (2) Accurate sliding fit of punch in barrel and die.
- (3) Keen edges on punch and die.
- (4) Travel of cutting end of punch beyond die to ensure complete ejection of the discs.

Weight considerations determined the choice of aluminium for the cutter body and, to facilitate construction of the prototype, the die was integral with the body. A punch and insertion die of harder metal such as stainless steel would add little to the total weight and would have more durable cutting edges.

PLATE XII



The leaf-sampling disc-cutter in use.

THE PRODUCTION OF CIDER FRUIT ON BUSH TREES. VINTAGE QUALITY TRIALS: CONCLUDING REPORT.

By L. F. BURROUGHS.

Earlier progress reports (1, 2, 3) have dealt with the juices and ciders produced in 1942, '43 and '44 from the Bush Trial plots planted in 1935. In this concluding report these earlier results are examined in the light of more recent findings. The technique of small-scale vintage quality trials described in 1945 (4) has remained unchanged in principle throughout this period but has been improved in certain details, to be described in this paper. In recent years the need for greater standardisation of fermentation conditions has become increasingly evident and further improvements will be essential in the near future when a series of trial orchards now being planted comes into bearing.

Observations on yields and orchard behaviour of the varieties in the 1935 Bush Trials are recorded elsewhere in this Report (5). Certain varieties are shown to have been successful and to merit further planting; the vintage quality of these varieties is therefore of particular interest and short notes summarising the general characters of their ciders are given in this paper.

Experimental.

Vintage Quality Trials. The fruit was milled and pressed and the juice was fermented in glass jars (usually $2\frac{1}{4}$ or $3\frac{1}{4}$ gallons) to specific gravity 1,025, when the cider was clarified and bottled. The ciders were sampled after storage in the cellar for natural conditioning. Details of these small-scale methods of cider-making were described in the 1945 Annual Report (4); improvements made since that time are outlined below.

A temperature-controlled fermentation room was installed in 1952. This has greatly improved the facilities for standardising conditions of fermentation and has provided a better measurement of the rate of fermentation of different juices.

The procedure of centrifuging and filtering through a 30 cm. Seitz clarifying filter was superseded during the years 1945-47 by kieselguhr filtration without prior centrifuging. This was more economical of cider but the prototype filter proved difficult to handle and fluctuation in operating pressure sometimes caused leakage of kieselguhr through the candle. In 1948 a 20 cm. Carlson filter was used with K5 sheets and, although it was again necessary to centrifuge the ciders, this method has been more satisfactory.

The use of 2 per cent. SO_2 solution for sterilising the bottles proved unsatisfactory since the amounts of SO_2 retained by the bottles after draining were variable. This was thought to account in part for differences in the degree of natural conditioning sometimes observed between replicate bottles of the same cider. From 1952, therefore, all bottles were sterilised by autoclaving.

The improvements described above have given better standardisation of cider-making technique but the method is still not entirely satisfactory, since

both the primary alcoholic fermentation and the conditioning in bottle are carried out by the natural microflora. Consequently, bacterial fermentations frequently occur, with serious effects on the flavour of the cider, and the result of any single vintage quality trial may therefore be invalidated. The variable effects of the natural microflora can be minimised by careful consideration of results over a period of years and a reasonable estimate of the inherent vintage quality of a variety can be obtained. This state of affairs, is however, highly unsatisfactory, and if a valid assessment of a variety is required in a limited number of years the uncertainty associated with natural microflora must be eliminated. The alternative procedure of pure culture primary fermentation followed by artificial carbonation and sterile filtration of the cider has been applied successfully to a number of small scale ciders in the last three years. This has made possible much more accurate assessments of vintage quality of the fruit and it is now planned to devise suitable equipment to enable all small scale ciders to be treated in this way.

Chemical determinations. The following determinations were made on the freshly expressed juices: Specific gravity, titratable acidity, pH, tannin content, nitrogen content and rate of fermentation. From 1948 onwards specific gravity, titratable acidity and tannin content were determined on all ciders at the time of bottling and in 1951 and '52 these determinations were repeated when the ciders were sampled. Comparison of these analyses showed the extent of acid changes and was a useful indication of bacterial action.

Specific gravity: determined by hydrometer (N.P.L. tested) and corrected to a temperature of 15°C.

Titratable acidity: by titration with N/6.7 NaOH using a mixed indicator of bromthymol blue and phenol red (6).

pH: by glass electrode and Cambridge pH-meter.

Tannin: by Lowenthal titration. 1 ml. of sample added to 200 ml. H₂O containing 5 ml. indigo carmine indicator, was titrated with KMnO₄ (0.785 g./litre). Results, representing total permanganate-reducing substances, are expressed arbitrarily as percentage tannin (7).

Nitrogen: by micro-Kjeldahl digestion (8).

Rate of fermentation: represents loss in specific gravity (degrees S.G. per day) of a sample of juice incubated at 25°C.

Results.

During the years 1942-53 inclusive a total of 498 samples was received from seven centres* in addition to samples from the Long Ashton plot, where cover-crop and manurial treatments were also under investigation. In any one year, examination of a complete set of varieties from all centres was not possible because of the limited facilities available for cider-making trials and the irregular cropping of many varieties. In recent years the policy has been to concentrate on a few varieties of regular cropping and good vintage quality obtained from as many centres as possible. Consequently, for about half the varieties more than 10 samples of each has been examined, while for the remainder much less information is available.

*Newnham Bridge, Worcs.; Hereford, Heref.; Much Marele, Heref.; Compton Greenfield, Glos.; Poundisford, Som.; Whimble, Devon; Faversham, Kent.

On the basis of the first three years of cropping certain general trends were noted (3); in particular it was found that the composition of the juices and to some extent the flavours of the ciders were influenced by the site at which the fruit was grown. This was termed the "centre influence" and included all the effects of weather and management at the individual centres.

To investigate this centre influence more fully an examination has been made of data collected for the three varieties Yarlington Mill, Dabinett and Sweet Alford of which a large number of samples had been tested (60, 59 and 47 respectively). The average juice composition (specific gravity, acid, tannin and nitrogen contents) for each variety has been calculated (a) for each centre over the whole period 1942-53, and (b) for each year from all available centres. Notes on the organoleptic characters of ciders obtained from these juices have also been compared. From these data it is possible to make certain generalisations regarding the influence of each centre on vintage quality. These are given below and the conclusions made in the earlier report (3) are confirmed or modified where necessary.

In general it was found that, for a given variety, variation from year to year was greater than variation between different centres. It appeared that the general quality of the ciders was good in 1944 and 1949 and rather poor in 1945 and 1948; other years were intermediate. The distinctive effects of centre noted in the earlier years have become less apparent as the orchards have grown to maturity, possibly due to more uniform management once the trees were established. This has been manifested not only in the flavour of the ciders but also in the nitrogen content of the juices. In the early years, for instance, juices from Faversham and Much Marcle regularly had high nitrogen contents (10-20 mg./100 ml.) in contrast to juices from Poundisford, while in recent years juices from all centres have tended to lower N contents. This greater uniformity in N content may be one of the main factors causing the influence of centre on the flavour of the ciders to be less apparent in the later trials.

Juices from the *Poundisford* centre (discontinued after 1950) maintained their special features, namely high specific gravity and tannin and low nitrogen content and rate of fermentation. In later years the N content became extremely low (2-4 mg./100 ml.) and fermentations were undesirably prolonged. The ciders were usually of the rich, full-bodied type described previously.

Juices from *Faversham* (discontinued after 1950) remained of rather high N content; for Yarlington Mill and Sweet Alford specific gravities were low. The ciders usually had a fruity aroma and flavour but were not otherwise distinguished.

The *Much Marcle* juices were similar to those from Faversham in showing a tendency to high N content, although specific gravities were not unduly low; their tannin contents were below average. In earlier years the ciders were fruity in aroma and flavour; in later seasons, however, they were often thin and lacked character although retaining some fruitiness.

Juices of Yarlington Mill and Dabinett from *Whimble* were of average composition and gave light ciders of fruity aroma and pleasant astringency. The performance of Sweet Alford at Whimble was outstanding; the juices were of high specific gravity relative to those from other centres and the ciders were invariably the best of this variety in each year.

Juices from the *Hereford* centre were of average composition; the early tendency to high tannin content (3) has not been confirmed. The aroma of the ciders was generally fruity and sometimes scented and the quality of flavour above the average.

The *Newnham Bridge* centre gave juices of low N content and Dabinett juices of low tannin. The ciders generally were only of average quality, although several very good Dabinetts were obtained.

Juices from *Compton Greenfield* have in recent years tended to be very low in nitrogen content and some fermentations have been extremely slow. The ciders in general had little character with the exception of two excellent Dabinetts.

The *Long Ashton* juices were usually of average composition and gave ciders of pleasant aroma and flavour with some fruitiness. The hardness previously noted (3) was not apparent in later years.

Other conclusions made in the earlier progress report (3, p. 180) require only minor modification. It was stated that in general the centre influence had been impressed on all varieties tested. In later years this feature has been rather less marked although still discernible for certain centres, in particular Poundisford and Faversham. The excellent vintage quality of Sweet Alford from Whimple is, however, worthy of note and may be associated with the fact that this variety is a native of Devon.

The retention of the vintage character of varieties grown as bush trees, previously noted (3), has been confirmed. It appears, however, that the composition of the juice may be slightly influenced by this method of culture. Thus, it has been found (9) that juices from bush trees have slightly higher specific gravities and tannin contents and slightly lower acidities and rates of fermentation than juices of the same varieties from standards. The evidence for these differences, although based on a large number of samples, cannot strictly be regarded as conclusive since the sources of the two types of fruit were unrelated.

Comparison of the two rootstocks Crab and Malling I at centres other than Long Ashton had to be abandoned after the earlier years. The absence of any consistent difference due to rootstock (3) has, however, been confirmed by statistical examination of the juice composition of samples from Long Ashton (3 varieties, 1947-50); similarly, no consistent differences were observed in the vintage qualities of the respective ciders.

The production of many excellent ciders in the course of these trials has amply demonstrated the potential high vintage quality of fruit from bush trees and fully justifies the conclusions made in the earlier report (3). At the same time there have been many failures but these have usually been attributable to abnormalities in fermentation, especially during natural conditioning in the bottle: this risk of failure will remain until the uncertain effects of fermentation by the natural microflora have been eliminated. The adoption of pure culture fermentations, as outlined in an earlier section, would greatly improve the precision of future vintage quality trials.

The Vintage Quality of Varieties of Good Orchard Behaviour.

The average juice composition and vintage quality of the varieties described by Williams (5) as successful or moderately successful in the trials

are given below. It must be emphasised that these observations are generalisations based on a limited number of samples (9) and it is possible that a *single sample* of any given variety may differ considerably from the stated description.

Bulmer's Norman. (18 samples). Medium bittersweet (acid 0.22% ; tannin 0.29%). Juice tends to ferment rapidly giving ciders with rather harsh tannin bitterness and lacking body.

Dabinett. (59 samples). Medium bittersweet (acid 0.15% ; tannin 0.32%). Ciders often have aromatic aroma and flavour, with soft astringent tannin, and are full bodied and fruity.

Sweet Alford. (49 samples). Sweet (acid 0.20% ; tannin 0.18%). Ciders are soft and fruity, often with a suggestion of tannin although the variety is normally classified as a pure sweet.

Yarlington Mill. (58 samples). Medium bittersweet (acid 0.22% ; tannin 0.34%). Usually rather a light cider, sometimes fruity.

Chisel Jersey. (13 samples). Medium to full bittersweet (acid 0.18% ; tannin 0.51%). Ciders have a pleasant astringent tannin and a rich flavour and are full bodied.

Michelin. (11 samples). Mild to medium bittersweet (acid 0.25% ; tannin 0.27%). Ciders are usually rather thin and lacking in character.

Reinette Obry. (3 samples). Medium sharp (acid 0.52% ; tannin 0.12%). Pleasant fruity cider of medium body.

Sherrington Norman. (6 samples). Mild to medium bittersweet (acid 0.19% ; tannin 0.28%). Cider of average quality.

Ellis Bitter. (15 samples). Mild to medium bittersweet (acid 0.20% ; tannin 0.24%). Cider of average quality with some tannin astringency.

Perthyre. (17 samples). Very mild bittersweet (acid 0.16% ; tannin 0.18%). Cider of medium body, soft and pleasant.

Red Jersey. (No samples have been examined).

Stoke Red. (26 samples). Bittersharp (acid 0.64% ; tannin 0.31%). Fruit gives a good yield of juice, usually of rather low specific gravity and slow fermenting. Cider often has a scented aroma and a pinkish colour ; flavour both astringent and bitter, rather hard but very fruity.

White Close Pippin. (16 samples). Medium bittersweet (acid 0.21% ; tannin 0.39%). Cider of average quality with some tannin astringency and medium body.

Summary.

- (1) The results of vintage quality trials of cider fruit grown on bush trees during the years 1942-53 are summarised. The conclusions made in earlier Progress Reports are confirmed or modified.
- (2) The locality at which the fruit was grown is shown to influence the composition of the juice and the vintage quality of the cider.
- (3) Recent improvements in the technique of vintage trials are described and the need for pure culture fermentations is emphasised.
- (4) Notes are given on the vintage quality of twelve varieties of good orchard behaviour.

Acknowledgments.

The author expresses his thanks to the many people who, during the course of these trials, have been concerned with the growing and harvesting of the fruit and with the cider-making operations and the analysis of the juices and ciders. Mention can be made of only a few : Mr. F. W. Beech for the organisation of the vintage quality trials in recent years, Mr. J. H. Llewellyn for small-scale cider-making operations, and Misses Yvonne P. May and Shirley J. Locke for assistance with the analytical work.

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THE PRODUCTION OF BOTTLED CIDERS FREE FROM DEPOSIT.

By F. W. BEECH.

Introduction.

From the number of enquiries received at the Research Station it is apparent that the smaller cider-makers are being increasingly presented with the problems involved in the production of stable bottled ciders, whereas in the past the bulk of their production was directed towards draught ciders and bottling techniques were mainly the concern of the larger factories.

Two methods of bottling are in general use : cold sterilisation by filtration before bottling and pasteurisation after bottling. The first method requires continual checking by suitably trained personnel if contamination is to be avoided : the lack of such technical staff in many cider factories has accordingly brought the second method into greater favour. The use of pasteurisation does not, however, dispense with control measures since pasteurised ciders may be unstable if there are too many micro-organisms in the ciders at the time of bottling or if the pasteuriser is inadequately maintained ; thus either method calls for some degree of control. The necessary measures are outlined in the following article together with a description of modern bottling plant and sterilisation methods.

Bottling Plant and Sterilisation Methods.

Siting.

The siting of the bottling room and its equipment is most important. There is evidence that yeasts can be carried by air currents on particles of pollen, dried pomace or dust. Hence the bottling room should be on the windward side of the factory. In the bottling room, again, the filling machine should be nearest the cleanest air, while the returned empties store and bottle washing machine should lie to leeward. In modern bottling plants these sources of infection are placed in a separate room and the washed bottles are delivered by a covered conveyor to the filling machine.

Cold Sterilisation Method.

Equipment.

The following items of equipment are essential for this method. Those shown in parenthesis may be needed for temporary storage of the cider if the outputs of the different machines are not matched.

Clarified-cider tank.

Carbonator.

(Carbonated-cider tank).

Sterile filter.

(Sterile-filtered carbonated-cider tank).

Filling machine.

Crowner, corker or stoppering machine.

Ancillary equipment includes a bottle washer, pipelines and a source of top pressure for the filling machine.

The wooden vats commonly used for the temporary storage of the unsterile, clarified cider are usually satisfactory if they are emptied and washed out at frequent intervals. If this is not done, especially in hot weather, heavy yeast growth may develop in high nitrogen ciders: this may rapidly choke the sterilising filter so that a satisfactory output is not obtained. Suitably lined metal tanks, in a chilled store, are better although more expensive to instal.

A batch or continuous carbonator may be used according to the volume of cider being bottled. Batch carbonators are more difficult to clean, need more labour to operate and are often a source of metallic contamination unless the cylinders are made of stainless steel.

The carbonated cider should be stored in stainless steel or lined-metal pressure tanks fitted with refrigerated jackets or internal cooling coils. A manhole should be provided so that the tank can be cleaned easily.

The sterilising filter is the most important item in the bottling line and provided it is used according to the manufacturer's instructions it will remove all organisms from the cider. It is most important that the cider should be brilliant before it reaches the filter so that the filter need not function as a clarifier. The filter pads should be replaced when the pressure difference between the inlet and outlet reaches the stated danger level.

The sterile-filtered, carbonated cider can be stored in the same type of refrigerated, pressure tanks discussed above, provided they are capable of being sterilised before use.

The filling machine should be designed specifically for sterile bottling. Such machines have the following characteristics: (i) the air in the empty bottles is vented to the atmosphere without coming into contact with the cider or top pressure chamber; (ii) the top pressure air or carbon dioxide is sterile filtered before entering the machine; (iii) exposed filling nozzles are surrounded by circular shields in which a slight excess pressure of sterile air is maintained; (iv) the machine can be steam sterilised before use; and (v) the unsealed bottles travel in covered conveyors.

The filled bottles of cider can be closed with crown corks, screw stoppers or bark corks. Crown corks are less likely sources of infection than the other two forms of closure; in some sterile filling systems, as an extra precaution, the crown corks can be pre-sterilised before being placed in a pressurised, sterile filling hopper or they can be sterilised by a small flame just before being crimped on to the bottles. If the machine lacks these refinements the crowns should be kept in their sealed cartons until required and only as many taken out as will fill the hopper.

Screw stoppers are often inserted manually although machines are now available for the purpose.

It is difficult to seal bottles with bark corks under sterile conditions, for even though the machine is sterile, the cider may become infected either from the liquid extruded when a cork is compressed or from cork dust falling down the supply chute in automatic machines.

Ancillary Equipment. The correct use of bottle washing equipment is of the utmost importance. To ensure the sterility of the washed bottles, the machine is sometimes used in conjunction with a second machine which sterilises the washed bottles with sulphur dioxide. But unless the bottle steriliser is adequately vented, some of this gas can get into the bottling room and cause acute discomfort to the bottling operatives. An alternative is to

use sterile filtered water for the final rinse in the washer and to maintain a top pressure of sterile air at the covered discharge end.

In the absence of these safeguards the provision of clean and sterile bottles is solely dependent upon the correct operation of the hydro washer (Fig. 1). This, in effect, depends on the removal of all dirt and organisms from the bottles by jets of detergent followed by the destruction of the micro-organisms in the hot detergent tanks. The actual time needed depends on the temperature and concentration of the detergent. It is essential, therefore, that there should be accurate thermometers for indicating, and means for controlling, the temperatures of the liquids in the tanks. The alkalinity of the detergent solutions should be determined at the start of each morning and afternoon run and, if necessary, brought up to strength by the addition of fresh detergent. A marked change in the alkalinity of a tank indicates either that the curtains separating the upper sprays have perished and are ineffective, that there is a fracture in one of the tanks, or that one of the submerged steam heating coils is perforated.

If the insides of the bottles are to be adequately cleaned, the jets should send sprays of liquid vertically into the bottles. The jets should be correctly positioned and routine checks should also be made to ensure that the bottle carriers are aligned with the jets underneath; the driving chains should be adjusted if there is a general displacement. If the jetted liquid froths badly it is due to an admixture of air with the detergent solution. Air can enter the system either through faulty glands on the inlet side of the circulating pump or because the outlet in the detergent tank is partially exposed due to an insufficient volume of liquid. The individual jets need frequent checking in case they become partially blocked with scale or label pulp. If this blocking becomes severe, then either the detergent is incorrectly compounded for the type of water available or the screens that separate the washed-off labels are in need of renewal.

The warm rinse can be a source of contamination if it is of the recirculating type, for organisms grow rapidly in the warm water and recontaminate the clean bottles coming from the detergent section. The problem can be overcome by modifying the tank so that mains water, heated by passing through a coil in the detergent tank, is sprayed into the bottles and the collected waste used for the pre-rinse, or alternatively by connecting a chlorine injector or drip feed to the existing recirculated rinse tank, leaving a residual free chlorine content of 1 to 2 p.p.m. Recirculating water tanks often scale badly in hard water areas and the washed bottles develop a white film or bloom as they dry: blocks of proprietary water softening compounds added to the tank will prevent this.

The final rinse water is usually satisfactory if drawn directly from the town mains, but water from wells or storage tanks may be contaminated with yeasts. In such circumstances a small sterilising filter should be fitted in the water supply to the bottle washer.

Mains and Services. The most satisfactory method for conveying cider in the bottling room is a permanent stainless steel pipeline system, fitted with steaming points and drain cocks, but it is expensive to instal. As alternatives, glass pipeline or sweetened rubber hose may be used: the chief points to observe are that the first is suitably protected from mechanical damage and that the second is replaced when cracks appear in the inner surfaces. A new type of hose, consisting of a polythene inner tube with stainless steel couplings

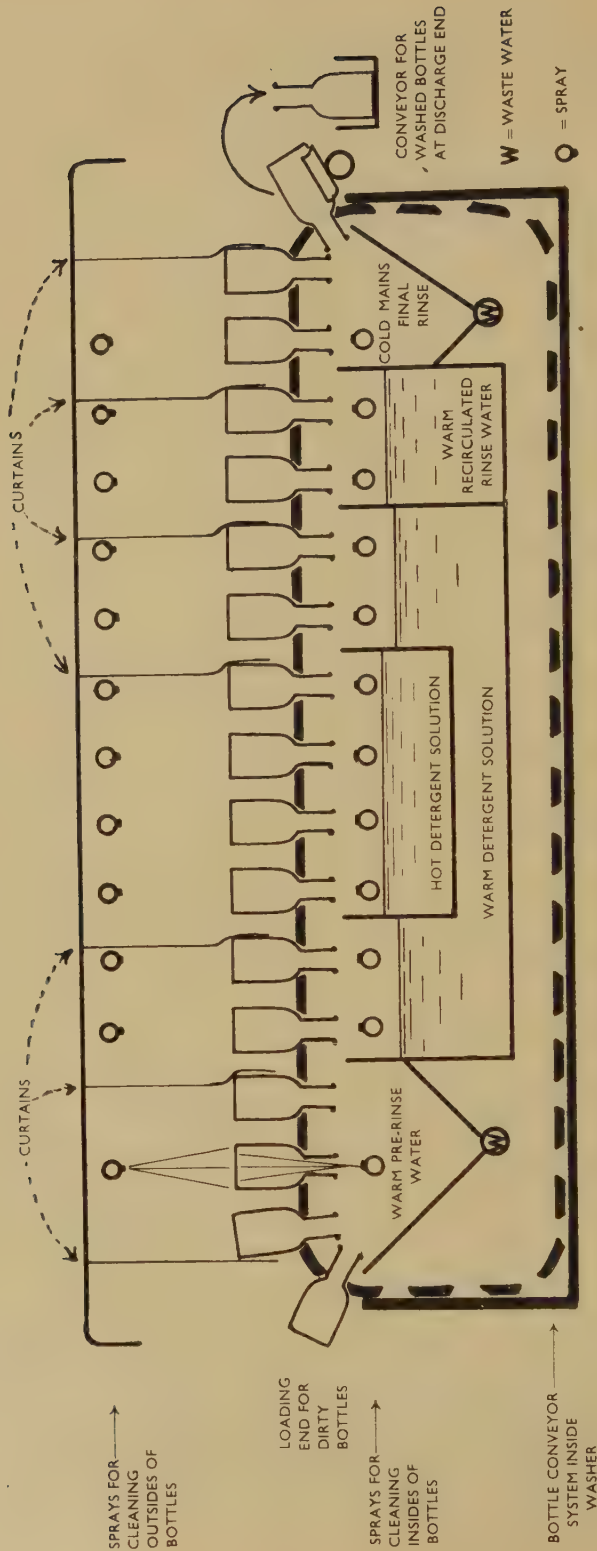


Fig. 1. Diagrammatic cross section through the centre of a typical hydro-type washing machine.

and wire mesh sheathing is now available ; this may prove a suitable alternative.

Compressed air or carbon dioxide is used for supplying top pressure to the filling machine. A small air sterilising filter should be fitted at the junction of the air line and the filling machine to prevent contamination during bottling and for sterilising the cooling air after the filling machine has been steamed. If air compressors are used an oil filter should be fitted into the supply line before the air sterilising filter.

Sterilisation Procedure.

Sterility should begin at the cider sterilising filter and be maintained in all the equipment through which the cider subsequently passes. A detailed working procedure cannot be given in an article of this nature since each scheme must be designed according to the layout of the plant and the materials of which it is constructed.

The cider sterilising filter must always be steam sterilised according to the manufacturer's instructions. If the tanks, pipelines and filling machine are heat resistant, steam is the most reliable sterilisation medium provided that steaming is continued until all the plant is thoroughly heated and that the plant is first cleaned internally with water or detergent solution. It is better to steam each item of equipment separately, in order to avoid the formation of excessive quantities of condensed water, and to connect them together before steaming is discontinued. The plant can be allowed to cool by admitting air through the inlets of the cider and air filters or by passing sterile water through the plant and displacing this with the bottling cider.

If steaming is not permissible solutions of chemical sterilising compounds may be employed. Using this method it is essential that the solutions cover all internal parts of the plant. For example, pipelines for conveying cider should be completely filled with sterilising solution but even this may not completely sterilise rubber hoses that are cracked internally. The top of the filling machine must be provided with a vent, otherwise the top pressure will keep the sterilising solution at the normal cider filling level. Filling machines with revolving heads should be rotated with bottles in position so that the solution can sterilise the filling nozzles. A common method is to circulate a hot detergent solution at 180°F. (82°C.) for 30 min. through all the equipment beyond the cider sterilising filter (1). The plant is then left overnight filled with a weak solution of a quaternary ammonium compound or chlorine (2) etc. to prevent re-contamination. Next morning this solution is displaced with sterile water before bottling commences. If only cold sterilising solutions are used, the equipment must be cleaned thoroughly before these are circulated. The penetration into valves and filling heads by solutions of chlorine, chloramine, SO_2 , formaldehyde and hydrogen peroxide can be improved by the addition of a wetting agent (3) : quaternary ammonium compounds do not require such additions.

Crown corks can be pre-sterilised with formaldehyde vapour and placed in the hopper of the crowning machine. If a flaming device is also fitted the crown corks should have aluminium foil liners. Crown corks should always be kept in sealed cartons in a store free from contaminating odours and maintained at the correct temperature and degree of humidity.

Screw stoppers with sound rubber rings are tumbled in a hot detergent solution, rinsed with warm water and then placed in a weak solution of SO_2 ,

chlorine or a quaternary ammonium compound: they are then used direct from the container.

Bark corks are soaked in cold water for 48 hours and "sterilised" by a further short soaking in 1% SO_2 solution. They should be used only for sealing bottles of high alcohol ciders since it is difficult to prevent contamination at the corking machine.

Bottle Pasteurisation Method.

Equipment.

The machinery required is similar to that for the cold sterilisation method except that there are no cider or air sterilising filters and no sterile cider tank, but there is the addition of a pasteuriser.

There are three methods of pasteurising: (a) batch tank or submerged process; (b) spray process; and (c) vapour process; the method used depends on the volume of bottled cider produced. For small factories (a) or (c) is required, whereas for larger factories (b) or (c) is preferable.

Pasteurisers are fitted with accurate temperature indicators whose readings should be checked at intervals to ensure that the capillaries have not been damaged mechanically.

If the factory is in a hard water area the incoming supply should be softened to prevent scaling of the plant.

Micro-organisms that produce unpleasant smells may develop in the cooler water tanks of spray type machines, using the cider from burst bottles as a source of nutrients. Automatic chlorination of the water, coupled with frequent clearance of the tanks, will prevent this condition. The sprays of this type of machine should be inspected periodically to ensure that they do not become blocked.

Efficiency of Pasteurisation.

Although pasteurisation can destroy all the organisms in the final cider, whatever their source, it is advisable to keep their numbers as small as possible. Heavily contaminated ciders need higher temperatures or longer holding times to ensure sterility; this in turn increases costs and may alter flavour. Therefore, although the bottling plant need not be sterilised it should be kept scrupulously clean to avoid the development of pockets of infection.

Normally, the holding section of the pasteuriser is maintained at 150–155°F. (65–68°C.), the temperature used depending on the microbial flora, acidity, nutritional status, SO_2 and alcohol content of the cider. The period for which the bottles are kept in the holding section depends upon their size, e.g. 20 min. for pints and 30 min. for quarts; the cider in the bottles reaches the pasteurisation temperature only towards the end of this holding period. This is illustrated in Fig. 2 which shows the temperature changes inside a bottle of cider during the pasteurising cycle of a batch tank machine.

Thus it is essential that the efficiency of the pasteuriser should be checked by passing a bottle of cider, fitted into a recording thermograph, through the machine together with the routine bottles at least once during each of the morning and afternoon runs.

Routine Checks on Microbiological Stability of Bottled Ciders.

Although few cider-makers have facilities for the detailed microbiological

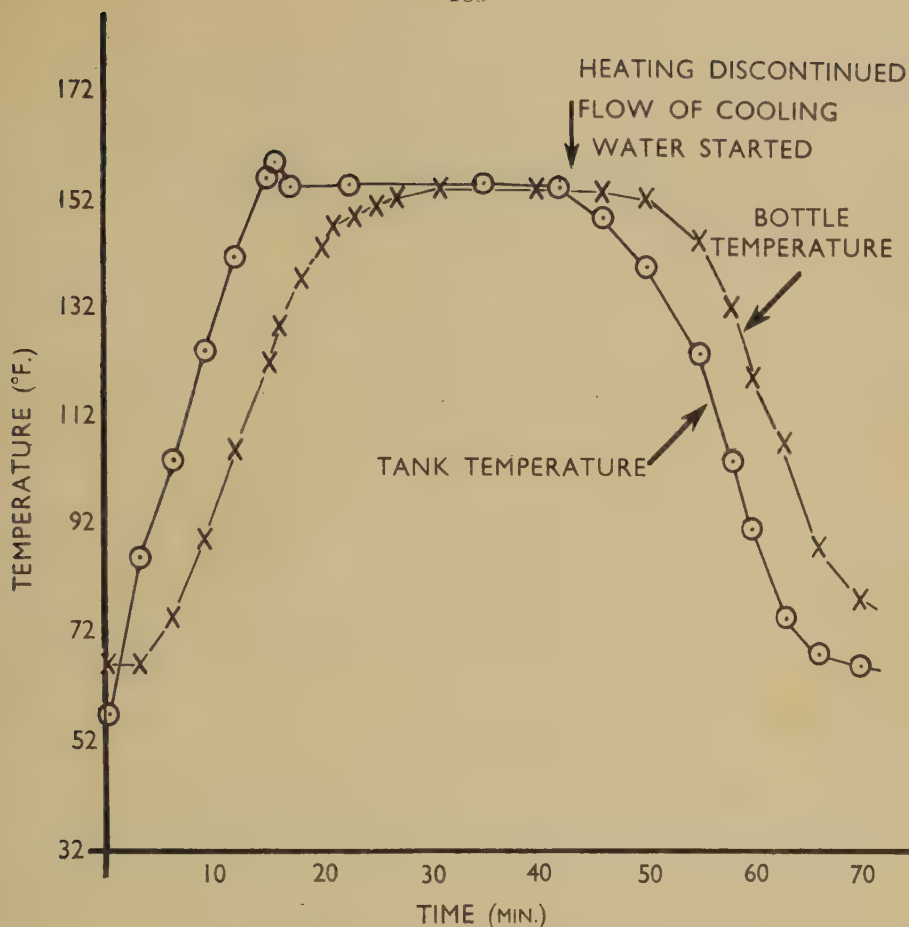


Fig. 2. Temperature changes inside the heating tank and inside a submerged bottle of cider during a pasteurisation cycle.

examination of their bottled ciders they can obtain a great deal of information by incubating samples selected from specified positions in the bottling line. The minimum requirements for this are : (a) a small, well-lighted room or cupboard maintained at 77°F. (25°C.) by thermostatically controlled heaters and fitted with slatted shelves ; and (b) a series of bottles taken from the washer, plugged with non-absorbent cotton wool, covered with a strong paper cap and heated at 300°F. in a domestic oven for 2 hours. These sterilised bottles should be stored in a clean cupboard until required.

Cider bottled by the cold sterilisation method should be sampled as follows :—

- (1) A sterile bottle, filled at the sampling cock on the outlet of the cider sterilising filter (see manufacturer's instruction manual) and sealed with a crown cork previously dipped in 60% industrial alcohol.
- (2) A sterile bottle filled on the filling machine and sealed with an alcohol sterilised closure.
- (3) A routine filled and sealed bottle removed from the bottling line.
- (4) A routine bottled cider sealed with an alcohol sterilised closure.

If there is a cider sterilising storage tank between the filter and the filling machine, a sample can be taken in a sterile bottle at the outlet of the tank as described under (1).

Sets of samples can be collected during the morning and afternoon runs, placed in the incubator and observed two or three times a week. All the samples should remain free of haze or deposit for at least one month. The results of these tests should be recorded so that a check can be kept on the stability of each batch of cider; this is made easier if the labels of the routine bottled ciders are dated or coded.

If hazes develop, an indication of the source of infection is given as follows:—

All samples hazy—sterilising filter not working efficiently.

(1) clear, (2), (3) and (4) hazy—infection between the filter and bottle.

(1) and (2) clear, (3) and (4) hazy—bottle washer not delivering sterile bottles.

(1), (2) and (4) clear, (3) hazy—infection from the closures.

When a sterilising system has been proved adequate, only samples (1) and (3) are needed and should these become hazy at a later date the complete sampling must be done until the infection has been eradicated.

For pasteurised bottled ciders only routine bottles need be collected morning and afternoon and incubated. If any of these become hazy then it is due either to a deterioration in the cleanliness of the plant or to inadequate maintenance of the pasteuriser.

Discussion.

The present public demand for bottled ciders, free from deposit, can be satisfied only if the cider-maker adopts the complete cold sterilisation method or pasteurisation after bottling. Pasteurisation is the most reliable method for the production of all products in factories without suitably qualified labour or of non-alcoholic or uncarbonated ciders in other factories. The cold sterilisation method has, however, distinct advantages if there is a large trade in flagon sized bottles, for pasteurisation can involve excessive breakage. Similarly cider-makers with a reputation for special vintage ciders may prefer the cold sterilisation method because they cannot take the slightest chance of damaging the flavour of their product. In short, the bottling method to be used must be decided by each cider-maker on the basis of cost, volume of production, labour available and the quality of his products. Both bottling processes may be necessary in a factory that is producing a variety of products in different sizes of bottles.

Summary.

The two systems for producing bottled ciders free from deposit are sterile filtration before bottling and pasteurisation after bottling. A detailed description is given of the necessary plant, maintenance and sterilisation procedures and a simple method for checking the stability of the final bottled ciders is suggested.

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A COMPARISON OF SOME VARIETIES OF VEGETABLES PRESERVED BY CANNING AND BY FREEZING: PROGRESS REPORT III.

By ALICE CRANG and MARGARET STURDY.

This report gives the quality assessment of some varieties of beans and peas that have been preserved by canning and by freezing in at least three of the years between 1949 and 1954. It also describes experiments, made in 1954, in which vegetables were preserved at different stages of maturity, two methods of cutting runner beans were compared and the percentage waste entailed in the preparation of peas and beans was determined.

Experimental.

Vegetables Used. All were grown at Long Ashton and preserved as soon as possible after picking. They were generally picked when considered to be at their prime for preserving; in 1954, however, each variety was picked on at least three dates, including one at which the vegetables were slightly immature.

Preparation. Broad beans and peas were shelled in the usual way. The ends of dwarf beans were cut off; the immature beans were then preserved whole and the mature pods halved longitudinally. The ends and the strings of runner beans were removed (unless of a stringless variety) and the pods were either sliced thinly or cut diagonally into slices about 1 inch wide.

The waste due to preparation was noted for each variety.

Canning Methods. The vegetables were preserved in A2½ S.R. cans, using the recommended proportion of vegetables to brine, processed at 10 lb. steam pressure* and stored at room temperature. Pea green colour (0.01%) was used for colouring the brine.

Freezing Methods. The prepared vegetables were scalded in boiling water, cooled in ice-cold water, put into airtight containers, frozen* and stored in a deep-freeze cabinet (temperature range —15° to 0°F.).

Judging Methods. The frozen vegetables were cooked, and the canned ones re-heated just before being judged. The same method of scoring was used as previously (1, 2). A score of 8.5 marks or more denotes outstanding quality; 8.4–7.5 good; 7.4–6.5 fairly good to fair; 6.4–5.0 poor to very poor; below 5.0 unacceptable. Coded samples, placed in identical glass bowls, were judged by 9 to 12 members of a tasting panel.

Results.

The mean marks awarded for the canned and frozen vegetables in the different seasons are given in Tables I and II respectively.

*See *Ministry of Agriculture Bulletin No. 21*, 8th edition, for processing details.

TABLE I.
CANNED BEANS AND PEAS.

Variety	No. of seasons	Colour		Texture		Flavour	
		Mean	Range	Mean	Range	Mean	Range
<i>Beans : Dwarf or Runner</i> Comtesse de Chambord	3	6.3	(5.8-6.9)	6.3	(5.6-6.9)	6.0	(5.6-6.7)
Masterpiece	4	6.1	(5.5-6.8)	7.4	(7.1-7.6)	6.0	(5.4-6.9)
Princeps	3	6.1	(5.5-6.5)	7.7	(7.5-7.8)	6.2	(5.8-7.5)
<i>Peas :</i>							
Dwarf Champion ..	3	6.1	(5.7-6.3)	6.2	(5.9-6.6)	6.0	(5.6-6.4)
Foremost	3	5.5	(4.8-5.8)	6.9	(6.8-7.0)	4.4	(3.8-4.9)
Lincoln	4	5.9	(5.0-6.8)	6.4	(5.6-7.3)	5.9	(5.4-6.1)
Onward	3	6.2	(6.0-6.4)	6.5	(6.0-7.4)	6.4	(6.1-6.9)
Petit Pois	4	5.6	(5.2-6.0)	7.2	(6.4-8.2)	5.8	(5.1-6.5)
Thomas Laxton ..	4	5.9	(4.9-6.4)	6.8	(6.3-7.8)	6.5	(5.6-7.3)

TABLE II.
FROZEN BEANS AND PEAS.

Variety	No. of seasons	Colour		Texture		Flavour	
		Mean	Range	Mean	Range	Mean	Range
<i>Beans : Dwarf or Runner</i> Comtesse de Chambord	3	7.1	(5.9-7.8)	6.4	(6.1-7.0)	7.1	(7.0-7.2)
Masterpiece	4	8.2	(6.5-9.1)	8.1	(7.4-8.7)	7.3	(6.6-8.0)
Princeps	3	8.6	(8.4-9.5)	8.2	(7.5-8.6)	7.4	(6.1-8.0)
<i>Peas :</i>							
Dwarf Champion ..	3	8.6	(8.1-9.2)	7.8	(7.1-8.4)	7.8	(7.6-8.2)
Foremost	4	8.8	(8.1-9.9)	7.8	(7.2-8.5)	7.7	(7.4-7.8)
Lincoln	4	8.6	(7.6-9.6)	8.0	(7.7-8.4)	7.9	(7.6-8.3)
Onward	4	9.3	(8.6-10.)	8.4	(7.7-9.1)	8.8	(7.9-9.3)
Petit Pois	4	7.8	(7.3-8.2)	7.9	(7.2-8.4)	7.6	(6.7-8.3)
Thomas Laxton ..	5	9.2	(8.2-9.8)	8.0	(6.7-8.6)	8.3	(7.3-9.1)

The superiority of the frozen over the canned vegetables was most striking in all respects.

The differences in quality between the vegetables processed when slightly immature, and those considered to be at their prime, are shown in Table III. As will be seen, the texture of the frozen, immature broad beans, dwarf beans

and peas was preferred, but with runner beans there was no difference : the method of cutting seemed of greater importance than the maturity ; the thinly sliced beans were of better colour and texture but of weaker flavour than those cut in slices about one inch across. The flavour of the mature runner beans and peas was considered to be better than that of the immature ones. Little difference due to maturity was noted in the canned vegetables.

TABLE III.
THE EFFECT OF MATURITY ON QUALITY.

	Colour		Texture		Flavour	
	Canned	Frozen	Canned	Frozen	Canned	Frozen
<i>Beans, Broad :</i> (mean of 6 varieties)						
Slightly immature	—	8.4	—	8.4	—	8.0
Mature	—	8.4	—	7.8	—	7.9
<i>Beans, Dwarf :</i> (mean of 4 varieties)						
Slightly immature	6.1	7.0	7.4	8.1	6.6	7.6
Mature	5.9	7.5	7.3	7.5	6.7	7.5
<i>Beans, Runner :</i> (mean of 4 varieties)						
Slightly immature, sliced thinly	5.5	8.5	7.8	8.6	6.1	7.2
Mature, sliced thinly	5.6	8.8	7.8	8.8	5.7	7.6
Mature, slices 1" across	5.0	8.0	7.7	8.0	5.9	7.9
<i>Peas :</i> (mean of 6 varieties)						
Slightly immature	—	9.1	—	8.2	—	7.7
Mature	—	8.9	—	7.9	—	8.1

TABLE IV.
WASTE ON PREPARATION.
(Percentage of total weight).

	Mean	Range
<i>Beans, Broad :</i>		
Six varieties	73	65-83
<i>Beans, Dwarf :</i>		
Ten varieties	15	3-27
<i>Beans, Runner :</i>		
Four varieties	28	20-38
<i>Peas :</i>		
Dwarf Champion	78	74-83
Foremost	75	70-79
Lincoln	63	59-70
Onward	75	71-79
Petit Pois	71	63-82
Thomas Laxton	72	65-77

Figures are given in Table IV for the percentage of waste in shelling the peas and broad beans, and in removing the ends and strings (where necessary) from the dwarf and runner beans. The proportion of waste was generally greater in the young vegetables, as would be expected.

Discussion.

Beans, Broad.

Triple White is the only variety of broad bean so far tested that has given a product with an acceptable colour when canned but, as it has been tested for only two seasons, it is not included in these results. All the varieties of broad beans so far examined have given satisfactory results when frozen.

The immature frozen beans were preferred for texture, but there was no appreciable difference in the colour and flavour due to maturity (see Table III).

Beans, Dwarf and Runner.

Comtesse de Chambord has given a poor quality canned product in three successive years; the colour and flavour of the frozen product have been fairly good, but the texture has been less satisfactory.

Masterpiece, when canned, has been similar in colour and flavour to *Comtesse de Chambord* but more satisfactory in texture. The frozen products have varied from one season to another, but the thinly sliced beans have each time been graded as very good in colour and good in texture.

Princeps has been similar in rating to *Masterpiece* when canned, and even better in colour when frozen. The flavour of the frozen product has varied from good to weak.

Peas.

The canned peas have all been rated poor in comparison with the frozen ones, but *Foremost* has been the only variety considered unacceptable on account of its flavour.

The colour of all the frozen peas has been outstandingly good in all varieties except *Petit Pois*; this was satisfactory, though a paler green. The texture and flavour of the variety *Onward* were very good, and all other varieties averaged good quality.

The waste on preparation was greatest for the variety *Dwarf Champion* and least for the variety *Lincoln*.

Summary.

Three varieties of beans and six varieties of peas have been preserved, both by canning and freezing, in three or more years since 1949.

Assessments of colour, texture and flavour have shown the frozen products to be markedly superior to those preserved by domestic methods of canning.

A slight degree of immaturity in the samples was found not to affect the canned products; it led to an improved texture in frozen broad beans, dwarf beans and peas, but weakened the flavour of frozen runner beans and peas.

Thinly sliced runner beans had after freezing a better colour and texture but a weaker flavour than those sliced diagonally into pieces about one inch thick.

Wastage on preparation has been found to range from 59 to 83% for peas, from 65 to 83% for broad beans and from 3 to 38% for dwarf or runner beans.

Acknowledgments.

We wish to thank Miss M. Hooper and Miss J. Sherborne for preparing and cooking the vegetables, and all the members of the tasting panel who so willingly helped with the judging.

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A COMPARISON OF SOME VARIETIES OF FRUIT PRESERVED BY BOTTLING AND BY FREEZING: PROGRESS REPORT V.

By ALICE CRANG and MARGARET STURDY.

The preserving qualities of fifteen varieties of raspberry and nine of strawberry were investigated during 1954. The fruit was grown at the National Agricultural Advisory Service Sub-Centre, Starcross, Devon, and compared when fresh and again after storage by bottling and by deep-freezing. The pH values and "soluble solids" contents of the samples were determined.

Preserving Methods.

The fruit was picked when ripe. Three representative samples of each variety were taken: the first was bottled the same afternoon, using jars with glass lids;* the second was sealed into Polythene bags, held in insulated containers cooled with solid carbon dioxide during transport to Long Ashton and transferred the same evening to a deep-freeze cabinet; the third sample was transported in 1 lb. punnets, held in a cold store overnight at about 40°F. and judged the next day for fresh fruit quality.

The proportions of fruit to syrup used in bottling and freezing were: 11 oz. raspberries to 5 fl. oz. of 40° Brix syrup, and 10 oz. plugged strawberries to 6 fl. oz. of 40° Brix syrup. The syrup for the bottled strawberries was coloured with 0.40% of a liquid strawberry red colour. No artificial colour was added to the raspberries or to the frozen strawberries.

Judging Methods.

The fresh fruit was judged the day after picking; the preserved raspberries after 4 months' and the strawberries after 4½ months' storage. The method of judging, in which 11 to 13 members of a tasting panel took part, was the same as that used previously (1). The allocation of marks is the same as that used for vegetables (2).

Raspberries.

The marks awarded for the fresh and preserved raspberries are given in Table I.

Preserving Methods.

The colour of the frozen raspberries was as good as that of the fresh fruit, whereas that of the bottled fruit (preserved without artificial colouring), varied from good to unacceptable. The raspberries generally remained whole when frozen; the texture of the bottled fruit was fairly good, and superior to that of the fruit bottled in 1953. The flavour of the frozen and bottled fruit was generally fair, and was rated above that of the fresh fruit, probably because the flavour of the preserved products was brought out by the added sugar.

* For method see H.M.S.O. Bulletin 21, 8th Ed. p.18 method II.

TABLE I.
RASPBERRIES.

Variety	Fresh			Bottled			Frozen		
	Colour	Texture	Flavour	Colour	Texture	Flavour	Colour	Texture	Flavour
Early Red	7.7	7.0	6.5	—	—	—	7.4	7.0	6.7
Landmark	6.5	7.7	6.1	—	—	—	5.7	7.4	6.5
Lloyd George ..	7.6	7.1	5.5	6.7	6.8	6.6	8.0	6.8	6.8
Malling Enterprise..	8.4	8.3	7.2	7.6	7.0	7.1	8.1	7.7	7.7
Malling Exploit ..	7.0	7.8	5.8	6.3	6.8	7.7	*6.4	*6.4	*5.3
Malling Jewel ..	8.0	8.7	6.1	7.0	7.1	6.1	7.8	7.4	7.2
Malling Promise ..	7.0	7.2	5.7	6.7	6.8	6.7	6.1	7.0	6.5
Malling V	7.0	8.2	6.2	5.7	6.8	7.3	7.7	8.0	7.2
Malling W	7.9	7.7	6.7	6.8	6.7	7.4	7.6	7.4	7.5
Malling Y	6.6	7.5	5.4	5.4	7.2	6.6	7.5	7.8	7.4
Malling Z	8.0	8.0	5.3	5.6	7.3	6.6	7.6	7.4	6.9
Milton	8.3	8.5	6.7	6.4	6.9	7.4	7.5	7.4	7.1
Preussen	6.9	7.2	5.4	4.7	6.9	5.9	6.0	6.4	6.3
Royal Scot	8.3	7.2	5.9	7.7	5.8	7.2	8.2	7.1	7.6
St. Walfried	7.7	6.4	6.0	8.2	6.0	7.2	8.2	6.5	7.1
Mean of 15 varieties : 1954	7.5	7.6	6.0	6.1	6.8	6.9	7.3	7.2	6.9
Mean of 15 varieties : 1953	7.4	7.5	6.3	5.6	6.2	6.3	7.3	6.9	6.4

* Frozen without syrup by error.

o Insufficient sample for bottling trials.

The varieties tested in 1954 include many not judged in 1953. Table II shows that the mean scores for colour and flavour of the seven varieties tested in both seasons were very similar but that both the colour and flavour of the bottled fruit were scored higher in 1954 than in 1953. This may well be due to differences in storage conditions. Although both sets of bottles were stored in the same place for the same length of time, the temperature was consistently higher in 1953 than in 1954. (Average maximum temperature July-September : 1953, 67.8° ; 1954, 64.7°F.).

Varieties.

The following varieties were tested during both 1953 and 1954.

TABLE II.
COMPARISON OF RASPBERRY VARIETIES 1953 AND 1954.

Variety	Colour					
	Fresh		Bottled		Frozen	
	1953	1954	1953	1954	1953	1954
Lloyd George ..	7.7	7.6	8.0	6.7	8.0	8.0
Malling Enterprise ..	8.1	8.4	5.7	7.6	8.2	8.1
Malling Exploit ..	6.9	7.0	5.0	6.3	7.2	6.4
Malling Jewel ..	8.0	8.0	4.7	7.0	7.6	7.8
Malling Promise ..	6.6	7.0	6.4	6.7	7.0	6.1
Malling V	8.2	7.0	5.0	5.7	6.6	7.7
Malling W	7.8	7.9	5.5	6.8	7.5	7.6
Mean	7.6	7.6	5.8	6.7	7.4	7.4

Variety	Flavour					
	Fresh		Bottled		Frozen	
	1953	1954	1953	1954	1953	1954
Lloyd George ..	6.7	5.5	6.7	6.6	7.0	6.8
Malling Enterprise ..	6.7	7.2	6.4	7.1	7.1	7.7
Malling Exploit ..	4.7	5.8	5.9	7.7	5.8	5.3
Malling Jewel ..	5.8	6.1	6.5	6.1	6.3	7.2
Malling Promise ..	5.2	5.7	6.2	6.7	6.2	6.5
Malling V	7.4	6.2	5.8	7.3	6.0	7.2
Malling W	5.9	6.7	6.2	7.4	5.7	7.5
Mean	6.0	6.2	6.2	7.0	6.3	6.8

Landmark has given a light-coloured, acid fruit that tended to break up on processing. It was one of the poorest varieties tested in both seasons. It has not been included in Table II as insufficient fruit was available for bottling trials in 1954.

Lloyd George has been well coloured in the fresh and frozen fruit in both seasons. The sample received in 1954 was a poor one, as may be seen from the low marks for texture and flavour.

Malling Enterprise was considered one of the best varieties tested in 1954. In 1953 its appearance was good in the fresh and frozen samples, but its flavour was only fair and it did not bottle well.

Malling Exploit has been fairly good in colour when fresh and has varied between fairly good and very poor in the preserved samples. Its flavour has been poor except in the bottled fruit in 1954 when it was rated as good.

Malling Jewel had a good colour and texture that was well retained in the preserved fruit, but its flavour has been consistently weak.

Malling Promise has been rated between fairly good and poor as fresh and preserved fruit in both seasons.

TABLE III.

RASPBERRIES.

Variety	"Soluble Solids" content %		pH value	
	1953	1954	1953	1954
Early Red	—	9.0	—	3.2
Landmark	8.9	8.0	3.0	3.0
Lloyd George ..	7.5	8.2	3.2	3.4
Malling Enterprise ..	8.8	8.2	3.1	3.2
Malling Exploit ..	7.6	7.5	3.0	3.2
Malling Jewel ...	8.2	8.2	3.2	3.3
Malling Promise ..	8.0	8.4	3.1	3.2
Malling V	9.0	8.0	3.1	3.3
Malling W	8.7	9.0	3.2	3.1
Malling Y	—	8.5	—	3.2
Malling Z	—	8.0	—	3.2
Milton	—	8.5	—	3.3
Newburg	10.0	—	2.9	—
Norfolk Giant ..	7.8	—	3.2	—
Preussen	—	7.5	—	3.3
Royal Scot	—	8.0	—	3.0
St. Walfried	—	6.0	—	3.2
Mean	8.5	8.1	—	—
Range	7.5-10.0	6.0-9.0	2.9-3.2	3.0-3.4

Malling V was considered to be of outstanding quality when fresh when judged in 1953, but it did not preserve well. In 1954 the quality of the fresh fruit was not quite so high, but the frozen fruit was rated higher.

Malling W. The quality of both the fresh and preserved fruit was considered to be fairly good in 1954, whereas in 1953 the texture was only fair and the flavour poor throughout.

Of the varieties tested for the first time, *Milton*, *Royal Scot* and *Malling Z* had fresh fruit of good appearance but weak flavour; the flavour of the frozen fruit was rated fairly good. *Early Red* and *St. Walfried* were nearly as good as the previous varieties in appearance when fresh, and the latter variety was rated the best of the series for colour in the bottled and frozen fruit.

The varieties *Landmark* and *Preussen* were of poor quality. *Malling Y* was rated of poor quality when fresh and bottled, but fairly good as frozen fruit.

The soluble solids content and pH values of the varieties tested in 1953 and 1954 are given in Table III. There is a tendency for the soluble solids to be lower, and the pH values higher, in 1954 than in the previous year.

Strawberries.

Several of the strawberry varieties were tested for the first time in these trials.

A different artificial strawberry colour was used this season, but it proved too dilute in the proportions used: the marks given for the colour of the bottled fruit have therefore been omitted. (Table IV, Strawberries).

TABLE IV.
STRAWBERRIES.

Variety	Fresh			Bottled		Frozen		
	Colour	Texture	Flavour	Texture	Flavour	Colour	Texture	Flavour
Cambridge Early	7.2	8.2	7.3	5.5	6.0	6.8	5.8	6.0
Cambridge Favourite (422) ..	7.2	7.4	6.5	7.6	5.7	8.3	7.1	6.5
Cambridge Prizewinner (134)	8.0	7.8	6.3	5.9	5.7	8.7	6.8	6.4
Cambridge Rival	5.4	7.4	6.6	5.5	4.3	4.8	6.5	4.9
Cambridge Vigour (C.I.) ..	9.3	8.2	7.5	7.2	6.3	7.7	7.3	6.9
Cambridge 456	7.3	7.8	6.3	6.7	6.7	7.7	7.8	6.4
Huxley	8.5	6.6	6.4	6.1	6.1	7.3	6.4	5.4
Perle de Prague	9.0	7.9	7.3	6.9	5.9	7.8	6.7	5.8
*Royal Sovereign	6.6	7.8	7.8	6.9	7.3	5.2	7.8	6.9
Mean : 1954	7.6	7.9	6.9	6.5	6.0	7.1	6.9	6.1
Mean : 1949-53	—	—	—	7.4	6.5	8.2	7.7	7.0

*Sample under-ripe.

The low marks awarded for the flavour of the strawberries may have been due to the wet season, as the average soluble solids content of the fruit was lower and the pH values higher, than usual (see Table V).

TABLE V.
STRAWBERRIES.

Variety	“Soluble Solids” content % 1954	pH value	
		1951	1954
Cambridge Early	6.5	3.2	3.5
Cambridge Favourite (422)	5.0	—	3.4
Cambridge Prizewinner (134)	9.3	—	3.4
Cambridge Rival	7.9	—	3.7
Cambridge Vigour (C.I.)	7.9	—	3.4
Cambridge 456	8.0	—	3.5
Huxley	7.4	3.3	3.5
Perle de Prague	8.6	—	3.4
Royal Sovereign	9.0	3.4	3.5
Mean : 1954	7.7	—	
Mean : Previous years (3)	8.2	—	

Preserving Methods.

The frozen strawberries were greatly superior in appearance to the bottled fruit, but the differences in flavour were not marked. The quality of both the frozen and bottled samples was below the average compared with previous years.

Varieties.

Cambridge Early. The quality of the fresh fruit was fairly good, but the frozen and bottled fruit was poor. Previously it had frozen quite satisfactorily but had been poor when bottled (4).

Cambridge Favourite, Prizewinner and “456,” tested for the first time in these trials, gave fruits of satisfactory appearance when fresh and frozen but the flavour was weak throughout.

Cambridge Rival, also tested for the first year, had a dark “beafsteak” coloured fruit that was considered unattractive by most of the judges. The flavour of the bottled and frozen fruit was also disliked.

Cambridge Vigour proved one of the best of the series in this year’s trials, the colour and texture being very satisfactory after transport as fresh fruit and the flavour being second only to Royal Sovereign. The fruit preserved better than most in the series.

Huxley has proved again to have a well-coloured, but tough fruit. The flavour this year was considered to be poor.

Perle de Prague, tested for the first season, gave a very well-coloured fruit when fresh, and good when frozen, but the flavour was poor in the bottled and frozen fruit.

Royal Sovereign. This variety was only partly coloured when picked, and although this may be the normal market practice, it was unsatisfactory when the preserving was carried out on the same day. The flavour, however, was the best of the series in the fresh and preserved fruit. Previously this variety had proved disappointing in appearance when frozen (4) (5).

Discussion.

The appearance of some of the raspberry and strawberry varieties tested in 1954 was quite satisfactory, but lack of sunshine during the ripening period was reflected in the poor flavour of the fresh fruit. Low temperatures were also experienced during the storage of the bottled fruit and it is probably on this account that the bottled raspberries were of better colour and flavour than those bottled in 1953. This again shows the necessity for holding trials for several years before drawing definite conclusions regarding the quality of any variety.

The superiority in appearance of the frozen over the bottled fruit has again been demonstrated. Deep freezing is not suitable for all kinds of fruit, nor is it generally available, and so the need remains for more information on satisfactory varieties for bottling.

Summary.

The quality assessments of fifteen raspberry and nine strawberry varieties, tested as fresh, bottled and frozen fruit, together with the soluble solids contents and pH values, are discussed and compared with the results previously obtained. Probably due to lack of sunshine during the ripening period the fresh fruit was lacking in flavour compared with that of previous years; soluble solids were lower and pH values higher than expected. Most of the fruits were found to freeze well, but while most of the raspberries also bottled well, this method of preserving was not satisfactory with strawberries.

Acknowledgments.

We should like to thank Mr. F. A. Roach and Mr. W. C. Ibbett for arranging the collection of the fruit and for giving us facilities for preserving it at Star-cross; Mr. G. E. Clothier for meteorological data; Miss M. Hooper and Miss J. Sherborne for their assistance, and all members of the tasting panel.

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SOURCES OF VARIABILITY IN SAMPLING BLACKCURRANTS FOR LEAF SPOT.

By G. M. CLARKE and A. T. K. CORKE.

Experiments on the control of blackcurrant leaf spot have necessitated periodical assessments of the amount of infection on a number of experimental plots. Marsh (3) used a visual system to record the amount of foliage retained by the bushes on five occasions between mid-July and mid-October. In 1953 Corke (2) counted the numbers of infected and uninfected leaves on a number of shoots in each experimental plot. Statistical examination of results obtained by the same method during 1954 has shown that greater precision could have been obtained, with the same expenditure of effort, by modifications in sampling technique.

Method.

A rectangular plantation of 1,200 bushes of the variety Baldwin was divided into 24 plots, each of 20 bushes with guard bushes on all sides. Twelve plots were treated in one way (*T*), and twelve in another (*C*). Records were taken on a sample consisting of four bushes chosen at random from each plot of twenty. Six shoots per bush were chosen at random at the start of the season and marked for easy location at each recording date, when 20 leaves were counted on each shoot. From these records, an assessment of the variances between bushes (σ_b^2), and between shoots within a bush (σ_s^2) was made. Records were taken four times between early July and mid-September 1954; on the first occasion little disease was present, while at the end of the season there was a high incidence on all plots. Extremes of this type, with many bushes showing either 0 or 100% infection, are unsatisfactory for variance assessment; hence only the records taken on July 29th, when the mean infestation was 34%, were examined.

The statistical technique involved, that of "variance component analysis," is a simple application of analysis of variance methods to divide up the total between-bush variation into its components, σ_b^2 and σ_s^2 above, and is well exemplified by Cameron (1). Estimates of σ_b^2 , σ_s^2 were obtained for each of the 24 plots; there was no evidence of any relation between the size of these and the degree of infection. The average values of the variances were then calculated for the *T* and *C* plots separately, and a test was made to examine whether the variances differed according to treatment; again there was no evidence of difference. "Overall" estimates of σ_b^2 , σ_s^2 could therefore be calculated from the complete set of observations; these were $\sigma_b^2 = 131.83$, $\sigma_s^2 = 199.51$, so that a close approximation to the ratio σ_b^2/σ_s^2 is 2/3. (The units in which the estimates are expressed are those of the "angles of equal information" scale, to which percentages usually require transformation before analysis).

Each plot sampled contained $N = 20$ bushes; $n = 4$ of these bushes were taken in each plot, and $k = 6$ shoots taken within each bush. It is shown by Cameron that such a scheme yields a plot mean with variance $s^2 = \left(\frac{N-n}{Nn}\right) \sigma_b^2 + \frac{\sigma_s^2}{nk}$. This can be decreased, for fixed N and a fixed upper limit to nk ,

by altering n and k individually. The maximum number of leaves that could be counted with the labour available corresponded to $nk = 24$; samples might have been chosen in several ways ($n = 4, k = 6$; $n = 8, k = 3$, etc.) and each sampling scheme would yield a different value for s^2 . (No estimates of σ_b^2 or σ_s^2 were, of course, available on which to base a choice of scheme in this preliminary trial). The following table shows the effect of altering the sampling scheme so that nk does not exceed 24. ($s_o^2 = \frac{3s^2}{200}$ is tabulated for greater simplicity).

TABLE I.

$s_o^2 = \frac{3s^2}{200}$, WHERE s^2 = VARIANCE OF PERCENTAGE INFECTION ON A UNIT PLOT (TRANSFORMED FIGURES).

n (No. of bushes per plot)	2	3	4	5	6	7	8	9	10	11	12
k (No. of shoots per bush)											
2					0.4833	0.4000	0.3375	0.2889	0.2500	0.2182	0.1917
3				0.5000	0.4000	0.3286	0.2750				
4			0.5875	0.4500	0.3583						
5			0.5500								
6		0.7333	<u>0.5250</u>								
8	1.0875	0.6917									
12	1.0250										

Actual scheme used was $n = 4, k = 6$ (underlined).

It will be seen that there existed schemes with greater precision (smaller variance) than that actually adopted, requiring less labour in counting since $nk < 24$; e.g. $n = 6, k = 3$ ($nk = 18$) would have given $s^2 = 0.4000$, as compared with $s^2 = 0.5250$ in the scheme used ($n = 4, k = 6, nk = 24$). Further, for a fixed amount of available labour ($nk = 24$), the best deployment of it would have consisted in taking $k = 2$ shoots from each of $n = 12$ bushes. ($k = 1$ would not be permissible, as giving no estimate of σ_s^2).

Discussion.

Experiments to compare the effectiveness of methods of controlling black-currant leaf spot may be designed and analysed statistically. The choice of a sampling method is not at once obvious, since the incidence and spread of the disease are irregular within plots and bushes. Further, it is possible in a randomised layout of small plots for the disease to spread from control to neighbouring treated plots more easily than it might spread through a large, uniformly treated area. Thus the effect due to treatment may be rapidly obscured, and records should be taken from experimental plots in such a way that maximum precision (minimum plot-to-plot variance) is attained.

Leaf spot normally appears early in June and spreads rapidly, often causing severe premature defoliation. In the past, assessment of the amount

of infection has been made in one of two ways. One method was to record the percentage of leaves infected on shoots chosen at random and marked (2). Considerable labour is required to provide sufficient data by this method, so that only a limited number of bushes can be assessed on each occasion. Some errors arise from the formation of new leaves at the shoot apex ; furthermore, 100% infection may be reached comparatively early in the season, so that only a few sets of records can be obtained. However, differences existing early in the season can be recorded by this method before they become obscured. When the number of infected leaves reaches 100%, the amount of defoliation can be used as a measure of leaf spot (3). This method cannot be employed until the season is well advanced, but it is rapid and enables large numbers of bushes to be assessed.

It has been shown above that a redeployment of the labour available in 1954 for recording the percentage of leaves infected would have achieved greater precision had more bushes been sampled, with fewer shoots counted per bush. A method enabling records to be taken throughout the season from every bush in each plot would therefore be valuable. This might be achieved by the use of diagrams combining percentage defoliation with percentage leaf area infected, i.e. showing total percentage leaf area affected. Such a scheme would be rapid and simple, and would permit every bush to be examined without increasing the labour involved. Work on these lines is planned for 1955.

Acknowledgments.

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METEOROLOGICAL RECORDS, 1954.

Month	AIR TEMPERATURE (°F.)						RAINFALL (")			SUNSHINE (hours)			SOIL TEMPERATURE at 09.00 G.M.T.		
	Means		Dif. from average	Max.	Min.	No. of ground frosts	Total	Dif. from average	Most in a day	Total	Dif. from normal	Daily average	4"	8"	24"
	A Max.	B Min.													
January	43.2	32.1	37.7	55	17	23	2.82	-0.55	0.54	63.1	+15.2	2.03	38.1	39.2	43.7
February . .	44.7	33.4	39.1	55	16	17	3.67	+1.09	0.59	75.0	+7.9	2.68	38.3	38.6	41.1
March	50.1	37.4	43.7	61	21	14	3.45	+1.12	0.86	107.0	-15.6	3.45	41.8	42.1	43.7
April	55.8	36.8	46.3	64	31	18	0.79	-1.54	0.31	215.1	+55.7	7.17	46.3	46.3	47.8
May	60.6	44.3	52.5	74	35	5	2.21	0.38	0.61	146.4	-48.9	4.72	52.3	51.2	53.5
June	63.8	49.9	56.8	70	43	0	4.29	+2.18	1.09	152.5	-60.2	5.08	58.6	57.4	58.6
July	63.7	51.8	57.8	69	40	0	4.05	+0.89	0.69	121.8	-74.3	3.93	59.7	59.0	60.6
August	66.3	51.8	59.1	76	44	0	3.32	-0.33	0.52	146.3	-39.4	4.72	59.7	59.5	61.5
September . .	62.8	49.3	56.1	81	39	0	6.08	+2.93	0.75	164.8	+23.4	5.48	56.2	56.7	60.2
October	60.5	48.2	54.3	69	28	4	4.31	+0.46	0.66	87.8	-13.0	2.83	54.0	54.5	57.0
November . .	52.7	39.6	46.1	59	27	9	7.09	+3.39	0.82	46.6	-10.5	1.55	45.6	41.6	50.7
December . .	49.9	40.3	45.1	59	27	10	2.60	-0.97	0.51	47.4	+1.3	1.53	43.9	44.4	46.9
Totals or Means . .	56.2	42.9	49.5	-0.6			44.68	+8.29		1373.8	-158.4	3.76	49.5	49.2	52.1

G. E. CLOTHIER.

THE GROWTH OF CARROTS ON AN ACID SOIL.

By WILLIAM PLANT.

A.R.C. Unit of Plant Nutrition (Micro-nutrients).

Introduction.

A study of the nutrition of a series of annual crops on acid soils has shown that crop failure may be associated with multiple deficiencies of some elements (e.g. Ca, Mg, Mo) and excesses of others (e.g. Al, Mn) (1).

The present paper describes experiments, made in 1954, in which carrots were grown in an area of highly acid soils in which molybdenum deficiency in cauliflower and lettuce had previously been studied. Soils of this area, when suitably manured, produce some of the best market carrots in the West Country.

Hewitt (2), using sand-cultures, has shown that the carrot displays characteristic symptoms of manganese and aluminium toxicities when supplied with excessive amounts of these elements.

Methods.

The experiments were carried out at a site in Bromham, Wiltshire, on the Lower Greensand formation. The site was ploughed from permanent pasture in 1950 and used for trials of cauliflower and lettuce in 1950-53.

Eight treatments (Table I) were replicated three times. Gypsum (treatments 2 and 3) was applied in 1950; ground limestone (treatments 4 and 5) was applied in 1950 and again in 1953 after a fall in soil pH had been noticed. Soil applications of sodium molybdate (treatments 3, 6, and 7) were made in 1950 and 1953, and a molybdate spray (treatment 8) was given when plants were 8 weeks old. Mean pH values for the treatment plots (Table I) were determined in May, 1954. An annual dressing of an N.P.K. fertilizer (7.7.7) was given to all plots at the rate of 8 cwt. per acre.

Carrot seed, *var.* Early Scarlet Horn, was sown 14/6/54. During the growing period plants were scored for vigour, and visual symptoms were noted. Leaf samples were collected on 13/9/54 for determination of their molybdenum and manganese contents and yields were recorded on 2/11/54.

Visual Symptoms.

Except in the two treatments receiving lime all the young seedlings showed the marked purpling of the cotyledons that Hewitt (2) found in seedlings receiving excess aluminium; their growth was stunted. The purpling of the cotyledons and stems persisted till early August, when leaf margins were beginning to show the chlorosis associated by Hewitt with manganese toxicity. The general appearance of the plants at this time is shown in Plate XIII, Fig. 1 while Fig. 2 shows the chlorosis of the leaf margins.

When the crop was harvested in October marginal chlorosis had disappeared, though the plants remained stunted both in tops and roots.

Yields and Leaf Analyses.

Mean yields of roots and leaf analyses for molybdenum and manganese are given in Table I.

TABLE I.
YIELDS AND LEAF ANALYSES.

Treatment	Soil pH	Yield roots. Tons per acre	Leaf dry matter	
			Mo p.p.m.	Mn p.p.m.
1. Control	4.5	Crop failure	0.03	1290
2. Gypsum, 3 tons per acre	4.5	" "	0.06	1401
3. Gypsum, 3 tons per acre plus sodium molybdate, 2 lb. per acre	4.6	" "	0.04	1506
4. Ground limestone, 3 tons per acre ..	7.0	24	0.02	110
5. Ground limestone, 6 tons per acre ..	7.1	24	0.13	129
6. Sodium molybdate, 2 lb. per acre ..	5.0	Crop failure	0.05	1371
7. Sodium molybdate, 4 lb. per acre ..	4.8	" "	0.29	1388
8. Sodium molybdate (0.1%) sprayed on carrots 10/8/54	4.8	" "	1.90	1963

It will be seen that while both the treatments receiving lime produced 24 tons of roots per acre there was virtually no yield from any other treatment.

The level of molybdenum in the leaves of sprayed plants is significantly higher (at 0.1%) than that in all other treatments; the level in plants given 4 lb. molybdate per acre is greater than that in those receiving 2 lb. per acre (at 1.0%) and there is a higher level (at 5%) in plants given 6 tons limestone than in those given 3 tons per acre; the molybdenum concentration in the leaves from the 3 ton treatment does not differ significantly from that of the controls. There is no obvious correlation between the concentration of molybdenum in the leaf and the yield of roots.

On the other hand, the levels of manganese are well correlated with yield, the levels in the two treatments receiving lime being significantly lower than in any other treatment (at 0.1%).

It would therefore appear that molybdenum deficiency is not a factor limiting the growth of carrots on these soils and that good crops can be obtained once aluminium and manganese toxicities have been corrected by liming to pH 7.0.

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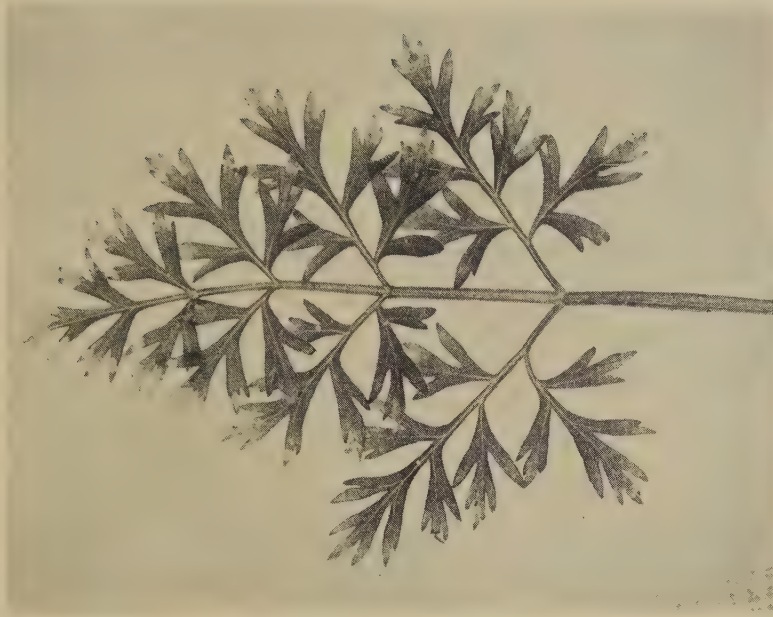
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Fig. 1.



A. B. C.
 Carrots A, B and C all the same age (8 weeks).
 A and B show differing severity of aluminum toxicity :
 note stunting of root and presence of cotyledons at A.
 C. Healthy carrot from lime treatments.

Fig. 2.



Leaf of 8-week-old carrot showing manganese toxicity.
 Note chlorotic edge effect : this was found on all treatments
 not receiving lime.

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